JOURNAL
OF THE
WASHINGTON ACADEMY OF SCIENCES

VOL. 44 April 1954 No. 4

PHYSICS.—*Mesons and nuclear forces.*[1]

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(Communicated by Richard K. Cook.)

1. HISTORY

I want to start out with some brief remarks about the history of the subject of mesons and nuclear forces. It is an example, as good as any I know in recent scientific progress, of both the wisdom and the folly of scientists. The theory of nuclear forces began in 1932 with the discovery of the neutron. This made possible a consistent picture of the structure of the nucleus, namely, to consider the nucleus as composed of neutrons and protons which are held together by very strong forces, different from and stronger than any other forces which we had known in nature before. Only three years after the discovery of the neutron and the start of nuclear theory, Yukawa suggested that the nuclear forces were transmitted between the nuclear particles, the neutron and the proton, by other particles, as yet undiscovered, which have now come to be known by the name of mesons. Yukawa predicted that there should be such particles, that they should have a mass of 100 to 200 times the electron mass, that they should be charged, and that they should have integral spin, probably either zero or one.

Three years later, Yukawa's prediction came true. Particles were discovered in cosmic radiation by two groups of people, Anderson and Neddermeyer, working at the California Institute of Technology, and Street and Stevenson, working at Harvard University. These particles had a mass of about 200 electron masses, they had a positive or a negative charge just as Yukawa had wanted, and they seemed to fulfill pretty well his program. In the succeeding nine years experimental physicists kept discovering more and more properties of these particles and theoretical physicists kept calculating what such particles would do for nuclear forces. Only the twain never met; the predictions of the theorists were completely different from the way the particles actually behaved.

The theorists predicted that these particles, the mesons, should interact very strongly with nucleons once they were formed and should, therefore, be easily absorbed, be easily scattered, and should easily cause nuclear reactions. They did nothing of the kind. In fact, they did nothing of any kind. They just moved along, were slowed down as any charged particle is, finally came to a stop and disintegrated in some way then unknown. All the same, theoretical physicists persisted in their belief in the connection between Anderson's cosmic-ray particle, and Yukawa's prediction. But the differences between the experimental results and the theoretical prediction were so great that it was proposed to make the best of another disagreement among physicists, one about the name of the particle, and to call the experimental particle, the mesotron, and the theoretical particle, the meson. Attempts to identify the two particles continued until finally, in 1947, a group of Italian physicists, Conversi, Piccioni, and Pancini, found that the cosmic-ray meson had even less interaction with the nucleus than had been suspected before. Even when they gave the meson a chance of sitting around the nucleus for a long, long time, namely a microsecond, even then it wouldn't

[1] The Twenty-second Joseph Henry Lecture of the Philosophical Society of Washington, delivered before the Society on April 24, 1953. This Lecture has also appeared in Physics Today 7 (2). 1954.

make use of its opportunity and would not get captured by the nucleus. This finally proved that the two particles could not be identified. But then it took only a few months before the solution to the puzzle was found in Bristol, England, by Occhialini, Powell, and Lattes, who discovered that there existed still another particle which they called the π-meson, the primary meson, which decayed after a short time into the meson which had been previously discovered and which they called the μ-meson, the "meson" meson.

The π-meson, at last, fulfilled Yukawa's dream. It had a strong interaction with the nucleus. Once created, it was easily scattered; it was easily absorbed by the nucleus; and since 1947 we have come to believe that the π-meson really is the particle which transmits nuclear forces. Many properties of the π-meson were discovered by the Bristol group, working with cosmic ray mesons and photographic plates, but the greatest progress about finding out the properties of this particle was only made after this particle was produced artificially in accelerators, first at Berkeley, then also at other laboratories. This again was an example of international cooperation: a powerful synchro-cyclotron, was available in Berkeley, but the Berkeley physicists did not discover artificially produced π-mesons until the special technique of reading photographic plates was brought to them from England by a Brazilian, Lattes. Since that time we have learned quite a lot about π-mesons, and this is what I want to talk about. However, before the main subject, it will be good to review some of the properties which had been predicted for the π-meson by nuclear physics on the basis of pure theory.

2. PREDICTIONS FROM NUCLEAR PHYSICS

In the first place, from nuclear physics it was predicted that the meson transmitting nuclear forces should exist in three forms, positively charged, negatively charged, and neutral. The positive and negative variety are easily visible. The neutral variety was only a theoretical prediction until 1949, based upon a very fundamental property of nuclear forces, namely, the so-called charge-independence. In 1935, it was discovered in the Department of Terrestrial Magnetism of the Carnegie Institution of Washington that the forces between two protons are just about the same as the forces between proton and neutron provided the pair of particles is in the same state of motion with respect to each other. This fact has, in the meantime, been established by many other pieces of experimental evidence, and by the theoretical work of Breit and others, and is known as the theorem of charge independence. Now if there were only charged mesons then there could only be processes of the type that Yukawa had predicted, namely, the following: A proton can emit a positive meson, thereby turning into a neutron, and then positive meson can then be absorbed by some neutron which may be in the neighborhood and which thereby is changed into a proton. A second *proton* in the neighborhood could not absorb the positive meson because thereby it would acquire two charges and that would give a particle which presumably does not exist. So in this way we can have an interaction between a proton and a neutron, but not between two protons. When proton and neutron interact, they exchange their charge, a kind of interaction which had been postulated in nuclear physics even before Yukawa and was known as exchange force. In fact the exchange character of the forces was one of the clues which Yukawa had when he invented his theory. However, you can see that by the exchange of charged mesons you cannot, in first order, get any interaction between two protons or between two neutrons; you need a neutral particle in order to transmit such interaction. That a neutral meson should exist was first postulated by Kemmer in England who set up a theory known as the "symmetric meson" theory. In this theory, neutral and charged mesons of either charge are all presumed to be coupled to the nucleon, and the strength of the coupling is supposed to be the same for all. (The proton and the neutron are both called by the generic name "nucleon.") Kemmer's theory leads indeed to charge-independence of nuclear forces.

After physicists were able to produce mesons artificially they found in fact the neutral meson in addition to the charged

mesons. The neutral meson unfortunately cannot be seen directly because it has an extremely short life. It decays within something like 10^{-15} seconds into two gamma rays. The short lifetime can be understood theoretically but I will not go into this problem.

A second point which nuclear theory predicted about mesons was that the mesons should not be scalar; a scalar particle is one which has no spin, in contrast to electrons and nucleons which have a spin of one-half—i.e., they have an angular momentum "around their own axis", somewhat like a spinning top. The term "scalar" implies more than the absence of spin; it also implies that the wave function of the particle remains unchanged when the entire space is reflected on a mirror plane. There is also the possibility that the wave function of a spin-zero particle changes sign upon such reflection; in this case, the particle is called "pseudoscalar." Now scalar mesons could be excluded because the nuclear forces resulting from them are central forces depending on the separation of the two nucleons and on nothing else, whereas experimentally the forces are found to depend also on the direction of the spins of the two nucleons. The third prediction of nuclear theory was that the mesons should be pseudoscalar. This was deduced, in fact, from the detailed dependence of nuclear forces on the direction of the nucleon spins, in particular from the sign of the quadrupole moment of the deuteron.

A fourth prediction comes from an entirely different field of physics—not from nuclear physics but from an investigation of the fundamental properties of fields which has been pursued with some success especially since 1947. The problem is the mathematical treatment of the interaction of two fields like the electric field, the field of mesons, of nucleons, of electrons, etc. Before 1947, the treatment of such interactions gave certain infinite results, but since 1947 we do know how to deal with these infinities. This is done by the so-called "theory of renormalization" in which the quantities which used to turn out infinite are re-interpreted as a change of the mass and the charge of the particle. After such re-interpretation, one can then show that all physically observable quantities are, in fact, finite. This modern theory of fields is further able to tell the sheep from the goats: certain theories *can* be made finite by renormalization, whereas others are intractable. You can write the fundamental equations of these other theories on paper, but when you try to calculate the probability of—let's say—the scattering of a meson by a nucleon, you will invariably find an infinite result. So this development of the theory of fields has given us a principle of selecting between possible and impossible expressions for fields and their interactions. In particular, a field consisting of charged particles, like mesons, which can be emitted and absorbed by other charged particles (nucleons), can only have spin zero. So in this respect the theory of fields confirms what nuclear physics had already postulated, namely, that mesons should have spin zero. And it said one more thing, about the coupling of the mesons with the nucleons, which I will discuss later.

3. PROPERTIES OF FREE MESONS

Now let us examine the experiments on mesons. There are many types of experiments that you can do with particles. The type of experiment which I shall discuss first is a simple one, which can be interpreted without elaborate calculations—just the qualitative result is sufficient to give an answer. First of all, the mass of the meson has been very accurately determined; it is 273 electron masses for the charged meson and 264 for the neutral meson. The difference may perhaps be due to an electric self-energy, i.e., due to the interaction of the electric charge of the charged meson with the electric field. Secondly, we know that the mesons have only a finite lifetime; the charged π-mesons live about 10^{-8} seconds. This is relatively long and makes it possible to observe them because, if you have a charged meson of this lifetime moving with a velocity close to that of light, then it will on the average go 10 feet before it decays, which is a sufficient distance to make observations. On the other hand, the neutral meson which lives for 10^{-15} seconds will travel only about 10^{-5} cm, which is not

enough to observe its properties before decay. The third property, which is a much more important one for our consideration, is the spin of the particle. This has been determined experimentally for both the charged and the neutral meson, by methods which are both ingenious and quite different.

The determination for the charged meson is based upon the statistical principle of detailed balancing. One knows from statistical mechanics and from quantum mechanics, that when you have a process which can go in one direction and then a process which can go the opposite way, the probabilities of these two processes must bear a close relation to each other. Namely, if all the types of particles involved were present at a very high temperature, such that there are equally many particles in each quantum state, then processes in both directions must occur equally often to preserve equilibrium. Now, what does this principle of detailed balancing have to do with the spin of the meson? If you have a particle of spin zero and if this particle is in an external field then there is only one way for this particle to behave: it can't orient anything with regard to the external field, it has only one quantum state. On the other hand, a particle of spin one can have three different orientations of its spin with regard to the external field. Now, let us consider a process in which a spin-one meson is produced and a process in which it is absorbed. If it is produced, it can be produced with three different directions of the spin. If it is absorbed, we know that it starts out with one definite direction of spin; therefore the ratio of the probabilities of being produced and being absorbed will contain a factor three if the particle has spin one, a factor which is known as the "statistical weight". If the particle has spin zero, on the other hand, the factor three is replaced by one, so that the ratio of production probability to absorption probability is three times smaller. This principle was suggested by Marshak for the investigation of the meson spin and was used successfully by two groups of experimental physicists, one at the University of Rochester and one at Columbia University. Both came out with the result that the meson, indeed, has spin zero as had been predicted by both nuclear physics and the general theory of fields.

A little more difficult was the next step, namely, to find out whether the meson is scalar or pseudoscalar; and now I must explain in more detail what this means. You probably know that atomic systems are characterized by a certain quantity which is known as the *parity*. The parity tells you how the wave function of the system behaves when you change the sign of all the coordinates, that is, when you change x into $-x$,y into $-y$,z into $-z$, i,e., when you make what is known as an inversion. In the case of zero angular momentum, you can do something simpler instead, namely, take a plane through the center of the atom and make a reflection of the whole space on this plane as if the plane were a mirror. Now let us ask what the wave function does when you make an inversion. We know that there are atomic states whose wave function does not change; we call these "even." There are other states whose wave function changes sign upon inversion, those we call "odd" states. This is the property that we call the parity. For instance, in optical spectra, any allowed spectral line leads from an even state of the atom to an odd state, or *vice versa*. Similarly, one defines the parity of nuclei. For instance, the deuteron consists of a neutron and a proton with a wave function which is even. At the same time the deuteron has an angular momentum of one, which comes from the spin of the nucleons being parallel, so we have an even state of spin one. Now suppose the deuteron is made to absorb a positive meson, then it will change into two protons. These two protons obey the Pauli principle, which says that the wave function of the whole system must be antisymmetrical, and which, therefore, says that there must be a certain relation between the spin of the system and the parity. It says, among other things, that it isn't possible to have any state of spin one and even parity but only of spin one and odd parity. This conclusion from the general principle of quantum mechanics is somewhat complicated to derive so I won't bother to do it.

Now, the way that the parity of the meson was determined was exactly by an experi-

ment in which mesons were absorbed by a deuteron. To start with, negative mesons were allowed to be captured in a Bohr orbit around the deuteron. When this happens, the meson will finally go into the innermost Bohr orbit which has zero orbital momentum and afterwards, if you wait long enough, it will be captured by the deuteron. Since it has negative charge, the meson will convert the deuteron into two neutrons which will then leave in opposite directions. Then one can ask whether this capture process is permitted by conservation laws. Now, as I said, the charged meson has no angular momentum to contribute; so you start out with an angular momentum of one and with a state of even parity of the deuteron. Then in the end you get two neutrons, and as I have just said about two protons, so also two neutrons cannot exist in a state of angular momentum one and even parity. Therefore, this process ought to be forbidden by the rule of parity conservation and angular momentum conservation—unless the meson itself contributes something to the parity. But actually experimentally, the capture of negative mesons by deuterons occurs with great eagerness, and it does give two neutrons. So we have to conclude that the meson contributes something to the parity, that it changes the parity of the system. This is precisely what is meant by a pseudoscalar particle; it is one which changes the parity of the nucleon system when it gets absorbed or emitted by the system.

4. COUPLING OF MESONS AND NUCLEONS

Therefore, up to this point, the experiments had confirmed exactly what the theory of nuclear forces had predicted. Now the next point is a considerably more difficult one and is perhaps the most important question in meson theory. This is the question of *how* the mesons are coupled to the nucleon. The coupling of mesons—the coupling of any two fields—is expressed by a term in the Hamiltonian of the system, and I am afraid I have to get a little bit technical at this point. The expression for the interaction will contain the two interacting fields. Now the meson is described by a wave function which I shall call ϕ; the nucleon wave function shall be called ψ; and the so-called adjoint wave function of the nucleon shall be $\bar{\psi}$. The coupling with a pseudoscalar meson will further contain the Dirac operator known as γ_5—which is a very recondite thing. The two expressions for the coupling which have been most used are then:

(1) $G\bar{\psi}\gamma_5\psi\phi$ direct or pseudoscalar coupling

(2) $g\bar{\psi}\gamma_5\gamma_\mu\psi\dfrac{\partial\phi}{\partial x_\mu}$ pseudovector coupling

The first of these is known as "direct" coupling; it contains the meson wave function itself. The second type of coupling which was almost exclusively used in the literature until 1947 contains the derivative of the wave function of the meson with regard to the coordinates; it also contains some of the more ordinary Dirac operators, γ_μ where μ runs from 1 to 4. These two couplings are also known as the pseudoscalar and the pseudovector coupling.

Now the pseudovector coupling has one practical advantage, namely, that it permits theoretical physicists to operate with quantities with which they are more familiar. It has, however, a grave disadvantage, namely, that it gives a field theory with which you can calculate only the first order approximation to any process; the second order gives infinite results for any quantity you calculate. This is connected with the fact that the theory cannot be renormalized. The pseudoscalar interaction has the disadvantage that it uses the abstruse operator, γ_5, which has the strange property that it likes to change a particle of positive energy into a particle of negative energy or, in terms of the hole theory, that the most likely process is the formation of a pair of nucleons. This makes theoretical calculations somewhat more troublesome, but on the other hand, the pseudoscalar theory has the great advantage that it can be renormalized in the sense of field theory and gives finite results for every process in any approximation. So one of the questions is which of these theories is right, and, of course, the theorists hope that the pseudoscalar coupling is right.

The factors G and g in (1) and (2) are simply constants which determine the strength of the coupling. I have written the

factor as capital "G" in (1) and as little "g" in (2) because the former is larger than the latter. A very important problem is clearly the determination of the coupling constant G or g; this plays the same role as the electric charge does in the interaction between charged particles and the electromagnetic field. This latter interaction is governed by the so-called fine-structure constant, $\frac{e^2}{\hbar c}$ which is 1/137 and, therefore, very small. On the other hand, the corresponding dimensionless quantity of meson theory, $\frac{G^2}{\hbar c}$, is about 15. This in contrast to $\frac{e^2}{\hbar c}$, is a large number, and this fact is the main cause of trouble in meson theory. All the methods which quantum mechanics has developed in the past were designed for small coupling between field and particle. This assumption of small coupling is very good for the electromagnetic field, and in this case we can predict effects of the order of one part in 10^9, and fit experiment, simply by making an expansion in powers of $\frac{e^2}{\hbar c}$. But it wouldn't be very successful to make an expansion in powers of $\frac{G^2}{\hbar c}$ which is 15: every successive order of approximation would give you a larger result than the previous one.

Now in exploring experimentally the coupling of mesons and nucleons, one turns to the simplest phenomenon which involves this interaction. This is the scattering of mesons by nucleons because it involves only one nucleon and one meson. A slightly more complicated phenomenon is the production of mesons by the interaction of electromagnetic radiation with nucleons, the photoproduction of mesons. In this case you have to consider, in addition to the meson and the nucleon, the interaction with the electromagnetic field. This interaction is known and simple. The next, more complicated, problem is that from which the theory started, namely the interaction between nucleons which is transmitted by the meson field. This is obviously more complicated because you now have to consider two nucleons and at least one meson. Finally, the most complicated of all phenomena that we hope to deal with is the production of mesons in the collision between two nucleons, in which case we not only have the mesons which produce the force between the two nucleons but, in addition, the meson which is produced in the process.

5. SCATTERING OF MESONS BY NUCLEONS

The scattering of mesons by nucleons has been investigated experimentally at various places, most extensively at the University of Chicago, with other important contributions by the teams at Columbia University and the University of Rochester. The results of these investigations seemed at first to be a major defeat for field theory because they seemed to agree with the pseudovector coupling. In making this comparison, the theoretical probability of scattering was calculated by the methods of perturbation theory, i.e., by using only the first term in a power series in $\frac{G^2}{\hbar c}$. In this approximation, pseudoscalar coupling gives a cross section for scattering of mesons by nucleons which is almost independent of energy, while pseudovector coupling yields a cross section which rises very rapidly with increasing energy. The experiments gave a very rapid increase of cross section with energy and thus favored the pseudovector coupling. However, the pseudovector coupling theory in perturbation (weak coupling) approximation predicted also some other things.

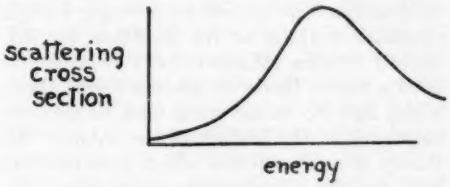
It predicted, for instance, that a negative meson interacting with a proton should in general be simply scattered. In principle, interaction between these two particles could also lead to the reaction $\pi^- + p = n + \pi^0$; (p = proton, n = neutron), but it was predicted by both pseudoscalar and pseudovector theories in the weak coupling approximation, that this reaction should not occur with sizeable probability. But experimentally, it does occur; in fact, the Chicago experiments show that it is about twice as powerful as the simple scattering of the negative mesons. Furthermore both theories in the weak coupling approximation predict that the positive-meson scattering should be about the same as the negative-meson scattering by protons. This again is wrong:

even if you add the charge-exchange scattering to the ordinary scattering of negative mesons, you still get only about a third of the probability of positive-meson scattering. The only possible conclusion from this is that the method of approximation is quite wrong, that one just can't get the right result by calculating merely the lowest power of G that occurs. If $\frac{G^2}{hc}$ is 15, this isn't very surprising. The situation is best illustrated by a song by Arthur Roberts, an experimental physicist of the University of Rochester, who says,

> We have weak coupling and we have strong coupling,
> And we have wrong, as we knew all along, coupling.

A more reasonable procedure was proposed by Brueckner of Indiana University and his collaborators, Case and Watson. Taking the strong interaction seriously, they said that nucleon and meson can easily form a sort of compound; i.e., that there exists a virtual quantum state of the system of meson and nucleon. Postulating such a state, they could make use of a lot of calculations which had been made in the period from 1940–45 in an effort to explain the discrepancies between the observed properties of the μ-meson and the theory, and which are known as the strong coupling theory. This theory had predicted that there should be stationary "compound" states of nucleon and meson, and that the first of these should be a state of the following characteristics: the meson has an orbital momentum one, the whole system has a spin of three-halves so that the state can be described as a $P_{3/2}$ state, and the system is further characterized by a quantity which is called the isotopic spin which also has the magnitude three-halves, $T = 3/2$. I will not explain what that means.

Now, Brueckner proposed that the phenomena of meson scattering are governed by this excited state. The energy of the state is then experimentally determined to be about 300 million volts higher then the ground state of the nucleon. The scattering cross section, both for positive and negative mesons by protons, should then have a resonance maximum near the stationary state and should thus go essentially like this:



The maximum, of course, can be expected to be quite broad because there is a very strong probability that the stationary state will decay into a free meson and a nucleon, and large decay probability is equivalent to a large width of the state.

The main success of Brueckner's theory was that he could predict the ratio of the cross sections for positive-meson scattering and negative-meson scattering. The ratio of the total cross sections should be three to one, which is very close to the observed ratio. Brueckner and his co-workers could further predict that the charge-exchange scattering of negative mesons should be about twice as large as the ordinary scattering of negative mesons and that again agrees with experiment. They could further predict that the angular distribution of the scattered mesons should be about $1 + 3\cos^2\theta$—and this again gives a reasonable approximation to the observed distribution, although it is far from a complete description.

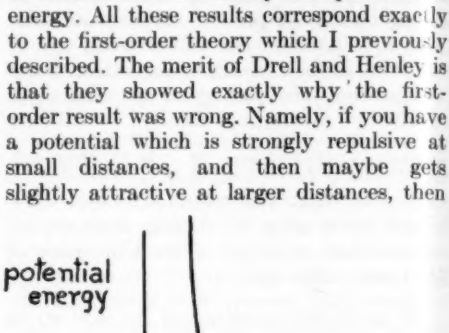
Scattering experiments are generally analyzed in terms of phase shifts of certain partial waves which describe the wave function of the particle. When this is done for meson scattering, it is found that the most important interaction is in the state $P_{3/2}$, $T = 3/2$. In addition to this there is also a strong interaction in the states of orbital momentum zero, that is in the S states, in spectroscopic notation, and that in this case there is strong interaction both for isotopic spin three-halves and for one-half. For three-halves there is strong repulsion; for one-half there is a somewhat weaker attraction.

6. THEORETICAL DEVELOPMENTS

Thus the Brueckner theory is quite successful, but, of course, it is purely phenomenological—the existence of an excited state is postulated but nothing is said about its

origin. It is desirable to go back to fundamentals in order to explain this state. The road to this was opened by a young French physicist working at the Institute for Advanced Studies, Maurice Lévy, who developed a meson theory of nuclear forces about a year ago. So we are going back to the very beginning of the history of the subject, the theory of nuclear forces which gave the first lead on the pseudoscalar interaction. By consistent use of the pseudoscalar interaction Lévy was able to account for the phenomena observed in nuclear forces. The most important discovery which he made was that, as a direct consequence of pseudoscalar meson theory, the forces between two nucleons are strongly repulsive at small distances. This was the clue that had been missing in previous theories in which the two nucleons had always been considered as perfectly fixed in space. Theory then showed that two such nucleons would always have a strong attraction, indeed so strong that the two nucleons would fall into each other, and not form a stationary state of finite binding energy. Lévy's discovery saved the situation because he showed that there was at small distances a very strong repulsion which prevented the two nucleons from falling into each other.

After Lévy's calculations physicists began to wonder whether the pseudoscalar theory could throw any light on the meson-nucleon scattering experiments. As I said before, the attempt to account for these experiments by weak coupling theory had been a complete failure. The first success with direct application of pseudoscalar theory was achieved by Drell and Henley of Stanford University. They were able to show that between nucleon and meson the same kind of potential exists as between two nucleons according to Lévy, namely one which has a tremendously strong repulsion at small distances. At somewhat larger distances there is an attraction, mainly in the $P_{3/2}$ state. The strong repulsion is independent of angle and, therefore, acts primarily in states of zero angular momentum, that is in S states. Now if you have a strong repulsive potential and calculate the resulting cross section in the first Born approximation, you get a tremendously large result. Since in our case the repulsive potential acts in S states, the scattering is isotropic. It is easy to see that it should also be nearly independent of energy. All these results correspond exactly to the first-order theory which I previously described. The merit of Drell and Henley is that they showed exactly why the first-order result was wrong. Namely, if you have a potential which is strongly repulsive at small distances, and then maybe gets slightly attractive at larger distances, then



the only effect of the repulsion on the wave function is to make it essentially zero at the point where the repulsion stops. The most this can do is to give a phase shift proportional to the radius of the repulsive region, and this phase shift will be completely independent of the *magnitude* of the repulsive potential. So Drell and Henley showed not only that the weak coupling theory was wrong all along, but also *why* it was wrong and what should be done instead.

The next major progress was made by Chew, of the University of Illinois who did the same for the attraction that Drell and Henley had done for the repulsion; namely, he showed how one could calculate, at least in principle, the effects of the attractive force in a sensible way without using perturbation theory. He was able to show that for the $P_{3/2}$, $T = 3/2$ state one should indeed expect a resonance if one only makes suitable assumptions about the magnitude of the coupling constant. Chew used pseudovector coupling for convenience in calculation, but his theory can easily be translated into pseudoscalar coupling.

Building on all this work we, at Cornell University, started last fall to attack the problem from the beginning using the pseudoscalar interaction between nucleon and meson. We were able to explain qualitatively most of the features observed in the scattering experiments. In the first place, we get a

strong repulsive interaction in the S state which gives an only moderately large S wave scattering, and this is just what the Chicago and Columbia experiments show. Then the theory gives an attraction in the $P_{3/2}$, $T = \frac{3}{2}$ state, and the phase shift in this state can be adjusted to fit the experiments by proper choice of the coupling constant. There is just one unknown in the theory, namely, the coupling constant; if you fix the coupling constant to be about 15 you can explain quite well the observed phase shift including its dependence on energy. Finally, you find from the theory that the phase shifts for all the other P states are very small, and this again corresponds to observation. There is only one point which is not yet explained: experimentally, there is an attraction in the S state of isotopic spin $\frac{1}{2}$. But here we know that the theory is still deficient, because although we know that one should renormalize the theory, we are only now learning how to do the renormalization in practice.

7. CONCLUSION

I think that one can say at present that although the pseudoscalar meson theory is not yet able to explain quantitatively the meson-nucleon scattering, there is no cause for disbelieving it, because there is no qualitative discrepancy between the predictions of the theory and the experiments. It is likely to be just a matter of learning how to treat strong interactions before we can get quantitative results on meson scattering.

The question of nuclear forces, as I said, is much more complicated. Lévy's first attempt was extremely valuable because it showed that in principle the theory gave the right behavior of nuclear forces. In detail, numerous theoretical physicists have criticized Lévy's paper, and this is not surprising. However, the theory can explain why nuclei hold together, why you have strong forces, and why nucleons do not completely fall into each other. It predicts the interesting phenomenon of many-body forces; that is, it predicts that you have interactions not only between two nucleons, but also between three or more nucleons which hand a meson to each other around the circle. Weisskopf and his collaborators have pointed out that these many-body forces may be quite important for the explanation of the phenomenon of saturation of nuclear forces, that is, for the phenomenon that heavy nuclei also do not collapse. We can deduce from the pseudoscalar theory that nuclear forces depend on spin and deduce that there is a quadrupole moment of the deuteron.

A word must be said about other mesons. The mesons which I have talked about are the π-mesons which have a mass of about 300 electron masses. There are a lot of other mesons of much higher masses. At one time when people calculated only the first-order interaction, some physicists suggested that maybe these heavier mesons would prevent the collapse of nuclei. I think this was false. I think, in fact, that one can see now that these heavier mesons have little to do with the structure of nuclei. This is again connected with Lévy's potential which I mentioned before, which gives a strong repulsion between nucleons at distances of about 0.5×10^{-13} cm. Now the heavier mesons could only cause forces of shorter range than this; therefore, no matter what these forces are, they will get swamped by the strong repulsion which exists anyway because of the interaction of the nucleon with the π-meson. Therefore, I think one does not need to know much about heavier mesons in order to construct a satisfactory theory of nuclear forces. Of course, when two nucleons collide at very high speed, they can penetrate the region of mutual repulsion, and then heavy mesons can be produced (as we know experimentally) and probably influence the mechanism of the collision in an important way. But nuclear forces at moderate energies, for instance inside ordinary nuclei, appear to be transmitted mainly by π-mesons which are coupled to nucleons by pseudoscalar interaction. I believe it is only a matter of mathematical skill, but of very great mathematical skill, to extract from the theory the information which we know is buried in it.

PALEONTOLOGY.—*New genera and subgenera of Lower Cretaceous ammonites.*

RAYMOND CASEY,[1] Geological Survey of Great Britain. (Communicated by Alfred R. Loeblich, Jr.)

The genera and subgenera diagnosed and briefly discussed in this paper are of Aptian and Albian age and are based partly on new discoveries in south-east England and partly on a revision of some previously described American and European material. The work has arisen as a consequence of research on the Ammonoidea of the English Lower Greensand formation, of which a systematic account is in preparation. Advance publication is given to the present contribution in order that its substance may be available for inclusion in the forthcoming *Treatise on invertebrate paleontology.*

I am indebted to Dr. L. F. Spath, of the British Museum (Natural History), and R. V. Melville, of the Geological Survey of Great Britain for access to the collections in their charge, and to C. W. Wright, who has communicated to me for study specimens and casts received from the U. S. National Museum and the Geological Survey of Canada.

Family Hoplitidae Hyatt

Subfamily Cleoniceratinae Whitehouse

Genus **Cleoniceras** Parona and Bonarelli, 1896

Neosaynella, n. subg.

Cleoniceras in which the umbilical bullae have disappeared and in which the falciform or sigmoidal costae normal to the genus have degenerated into obscure *Oppelia*-like crescents on the outer half of the sides. Venter tabulate in the early stages of development. Suture-line as in *Cleoniceras s.s.*

Type species.—*Cleoniceras* (*Neosaynella*) *inornatum*, n. sp.

Remarks.—*Neosaynella* is a specialized development of the stock which gave rise to *Cleoniceras s.s.*, and presumably is an expression of the same vital adjustments which led to the production of oxycones in other families. The subgenus is unique in the Hoplitidae in that it lacks both tubercles and true costae at all stages of growth, features which it might be considered desirable to emphasize taxonomically by full generic separation from *Cleoniceras.* The two groups are, however, connected by passage forms. Stratigraphical and morphological sequence indicate that *Neosaynella* is a secondarily smooth endform and that the laevigate condition is not an original feature inherited from its desmoceratid ancestors.

Occurrence.—Southeast England; Transcaspia. Lower Albian (*Douvilléiceras mammillatum* zone).

Cleoniceras (Neosaynella) inornatum, n. sp.

Fairly narrowly umbilicated platycone with strongly compressed, bluntly lanceti form whorl-section, widest at the umbilical border. Neanic whorls with a narrow, flat peripheral band which diminishes in width in the course of subsequent growth until the venter is acute. Umbilical wall subvertical, with angular rim. Radial line falciform. Outer crescents, with accompanying shallow depressions, about 18 per whorl, barely discernible before 30 mm diameter. Suture-line with asymmetric principal lobe and numerous auxiliary saddles, apparently similar to that of *C. cleon* (d'Orbigny).

Dimensions of holotype.—As follows:

Diameter (in mm)	51 (wholly septate)
Whorl-height (as per cent of diameter)	55
Whorl-thickness (as per cent of diameter)	23
Umbilicus (as per cent of diameter)	16

Remarks.—*C.* (*N.*) *inornatum* has a close analogue in *C.* (*N.*) *platidorsatum* (Sinzow) from the Mangyshlak Peninsula of Transcaspia. The Russian form (in which the originals of Sinzow, 1909, pl. ii, figs. 1–2, are here included) differs in its anguliradiate radial line and its wider, shallower first lateral lobe. Sinzow's species is dated by its association with *Sonneratia dutempleana* (d'Orbigny) and *Inoceramus salamoni* d'Orbigny, both being species of the *D. mammillatum* zone. The subgenus is also represented by other undescribed species in the English Lower Albian.

Occurrence.—Lower Greensand (top of Folkestone beds; *D. mammillatum* zone), Folkestone, south-east England. Holotype (Geological Sur-

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vey of Great Britain[2] no. 70409) and paratype (G.S.G.B. no. 74131), collected by the author.

Anadesmoceras, n. gen.

Moderately involute, discoidal Cleoniceratinae with distinct umbilical rim and flattened whorl-sides. Venter narrowly arched or sharpened in the adolescent, widening toward the aperture, which is preceded by wide sigmoidal constrictions. Indications of umbilical nodes and sigmoidal ribs on the inner whorls only. Test with striae of growth united into more or less distinct bundles, most prominent on the inner lateral area. Suture-line as in *Cleoniceras*.

Type species.—Anadesmoceras strangulatum, n. gen., n. sp.

Remarks.—This genus, like *Farnhamia*, described below, is a curiously localised development of the English Lower Albian. It is represented by a number of new species and has been referred to on a previous occasion (Casey, 1951: 98) as a link between the hoplitid *Cleoniceras* and the family Desmoceratidae. The constricted body-chamber and virtual smoothness give a desmoceratid aspect, but its affinities lie with the associated *Cleoniceras baylei* (Jacob) and *C. subbaylei* Spath. The latter has a similar striate test and in the course of growth shows the same changes in whorl shape, but is more distinctly ribbed and lacks the terminal constrictions. *Uhligella*, another link with the Desmoceratidae, has ribbing and constrictions of a different type and is not ventrally sharpened.

Occurrence.—Lower Greensand (Folkestone beds), Farnham area of Surrey, south-east England. Lower Albian (*Leymeriella tardefurcata* zone).

Anadesmoceras strangulatum, n. gen., n. sp.

Whorl-section very compressed, the sides very gently convex and convergent, subparallel at the aperture. Venter narrowly arched in the adolescent, becoming subacute on the posterior part of the body-chamber and then broadening rapidly towards the peristome. Umbilicus with flat, steeply sloped wall and distinct but blunt rim. Neanic whorls with about 10 very faint radially elongated nodes, directed obliquely forwards from the umbilical rim, each corresponding to three or four sigmoidal subcostae, barely visible except on the upper lateral area. Body-chamber, half a whorl in length, smooth except for growth striae and two or three sigmoidal, ventrally widening constrictions.

Dimensions.—As follows:

	*Holotype**	*Paratype 1* (body-chamber)	*Paratype 2* (septate)
Diameter (in mm.)	71	75	46
Whorl-height (as per cent of diameter)	52	49	52
Whorl-thickness (as per cent of diameter)	25	26	27
Umbilicus (as per cent of diameter)	17	17	17

* Maximum diameter c. 80 mm.; septate to c. 45 mm.

Occurrence.—Lower Greensand (Folkestone beds; top of *L. tardefurcata* zone), Wrecclesham, near Farnham, Surrey, southeast England. Holotype (G.S.G.B. no. Zm 1283), Paratype 1 (G.S.G.B. no. Zm 1281), Paratype 2 (G.S.G.B. no. Zm 1290), collected by the author.

Farnhamia, n. gen.

More or less evolute, compressed. Whorl-section subrectangular, the flattened sides converging to a broadly convex venter. Umbilicus with high, smooth, subvertical wall but no definite rim. Early whorls strongly costate, at first resembling a bluntly ribbed *Sonneratia* or *Tetrahoplites*, with the ribs arising in twos and threes from umbilical bullae and continuing across the venter with a forward sinuation. Costation, if persistent, tending to break up into long, untuberculated primaries and short intercalated secondaries, recalling that of *Parahoplites*. Outer whorls smooth or with only a few radial folds on the lower part of the flank. Suture line with subquadrate, more or less symmetrical, trifid first lateral lobe; saddles bifid, aborescent, progressively slender-stemmed and declining regularly toward the umbilicus.

Type species.—Farnhamia farnhamensis, n. gen., n. sp.

Remarks.—Farnhamia is the earliest known representative of the cleoniceratine branch which contains *Sonneratia*, *Tetrahoplites*, *Pseudosonneratia*, and *Protohoplites* and which lies in the direct line of ancestry of the Hoplitinae. Its discovery is thus of interest for the light it throws on the origin and interrelations of the primitive members of the Hoplitidae, and although as yet known only from a restricted area in southeast England, is likely to play an important part in European Albian chronology. Its appearance at the base of the *Leymeriella*

[2] Hereinafter abbreviated to G.S.G.B.

tardefurcata zone, along with *Anadesmoceras*, coincides with the incoming in North Germany of *Proleymeriella*, the first of the Leymeriellinae, another important branch of the Lower Albian Hoplitidae. This brings out the merit of Breistroffer's zonal classification, in which this burst of evolutionary activity is dated as the commencement of Albian time (Breistroffer, 1947).

Farnhamia was derived, probably, from *Uhligella*, and like that genus shows considerable variation in the duration of the costate stage. The innermost whorls are almost indistinguishable from *Sonneratia*, but the whorl-shape soon changes to that of *Tetrahoplites*. In that genus, however, the umbilical bullae are retained to a larger diameter, and the ribbing is sharper, persistent, and never modifies to a parahoplitid style. Adult specimens of *Farnhamia* attain an average diameter of about 300 mm, and detached portions of outer whorls may be strikingly similar to certain Upper Aptian *Parahoplites*. But generic discrimination may be readily made if the sutures are preserved, the breaking up of the umbilical lobe into numerous auxiliary elements being the chief diagnostic feature of the *Farnhamia* suture line as compared with that of *Parahoplites*.

Records of "*Parahoplites*" and "Desmocerate ammonites" from the "*jacobi* subzone" of the Farnham district (Wright and Wright, 1942) refer to *Farnhamia*. The accompanying "*Acanthohoplites*" and "? *Beudanticeras*" are here identified as *Hypacanthoplites* (including *H. trivialis* Breistroffer, group) and *Anadesmoceras*. Several folio plates would be required to illustrate the various species of *Farnhamia* now in the collections.

Occurrence.—Lower Greensand (Folkestone beds; 80–90 feet below the Gault), Farnham area of Surrey, south-east England. Lower Albian (base of *L. tardefurcata* zone).

Farnhamia farnhamensis, n. gen., n. sp.

Figs. 1, 4–9.

At diameter of 15 mm whorl-section but little compressed, sides convex, venter broadly rounded; arcuate ribs arise mostly in pairs, sometimes in threes, from obtuse umbilical bullae and traverse the venter as an obtuse-angled chevron with rounded apex directed forward. Whorls later increase in relative height and flatten at the sides; ribs slightly sigmoidal, without definite bullae, blunt on the test, sharper on the internal mold. Maximum vigour of costation attained at 45–55 mm. diameter, after which ribs fade from the middle of the sides, the umbilical portion remaining as thick, radially elongated folds or bulges, the ventral portion as heavy folds, separated by interspaces equal to their width. Umbilical and ventral ribs in proportion of about 12 to 24 at 70 mm. diameter. Ribbing lost at about 120 mm. diameter. Outer whorls smooth and more convex in section.

Dimensions.—As follows:

	*Holotype** (near beginning of body-chamber)	*Holotype* (penultimate whorl)	*Paratype 1*† (septate)
Diameter (in mm.)	228	155	60
Whorl-height (as per cent of diameter)	?	43	42
Whorl-thickness (as per cent of diameter)	?	34	?
Umbilicus (as per cent of diameter)	28	?	23

* Maximum diameter 250 mm.; septate to c. 200 mm.
† Crushed laterally.

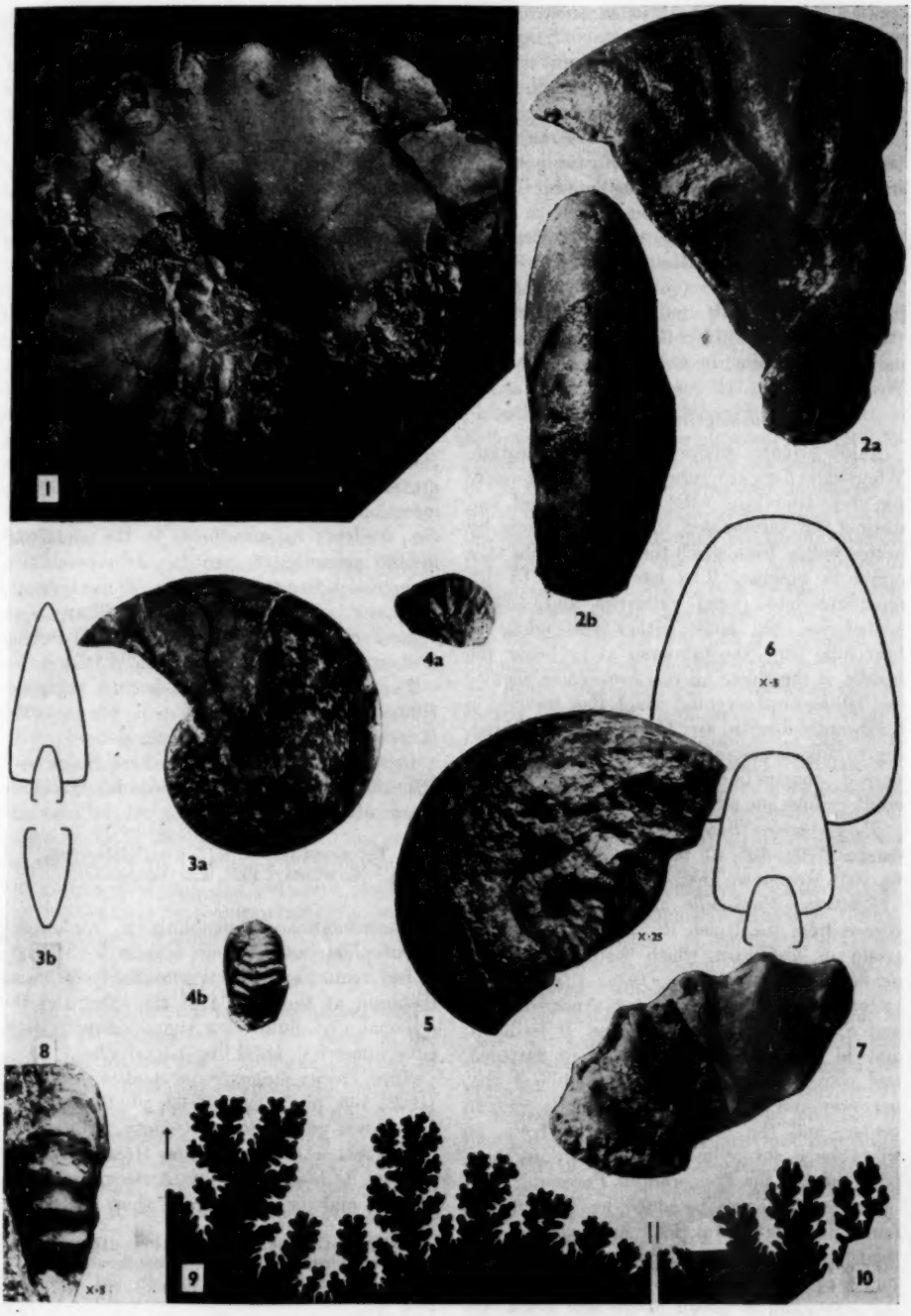
Remarks.—In *Farnhamia farnhamensis* the ribbing is lost before the onset of the "*Parahoplites*" stage. The costate nucleus thus re-

FIGS. 1, 4–9.—*Farnhamia farnhamensis*, n. gen., n. sp.: 1, Side view of paratype 1 (G.S.G.B. no. 85850) ×1; 4, side view (a) and ventral view (b) of paratype 2 (G.S.G.B. no. 85848) ×1; 5, side view of holotype (G.S.G.B. no. 74128) showing smooth outer whorl, ×0.25; 6, diagrammatic whorl-section ×.5; 7, side view of paratype 4 (C.W. and E.V. Wright Coll.) (internal mold) ×1; 8, ventral view of inner whorl of holotype (G.S.G.B. no. 74128) ×0.5; 9, external suture line of paratype 3 (G.S.G.B. no. 85849) ×1. Lower Greensand (Folkestone beds; base of *L. tardefurcata* zone), Coxbridge pit, Alton Road, west of Farnham, Surrey, southeast England.

FIG. 2.—*Anadesmoceras strangulatum*, n. gen., n. sp., side view (a) and ventral view (b) of holotype (G.S.G.B. no. Zm 1283), ×1. Lower Greensand (Folkestone beds; top of *L. tardefurcata* zone), Wrecclesham, near Farnham, Surrey, southeast England.

FIG. 3.—*Cleoniceras* (*Neosaynella*) *inornatum*, n. sp., side view (a) and diagrammatic whorl-section (b) of holotype (G.S.G.B. no. 70409), ×1. Lower Greensand (Folkestone beds; *D. mammillatum* zone), Folkestone, Kent, southeast England.

FIG. 10.—*Farnhamia* sp., internal suture line (incomplete) of near adult specimen (G.S.G.B. no. 74134) ×1. Locality and horizon as for Figs. 1, 4–9. Originals of all figures (except fig. 7) collected by the author.



FIGS. 1–10.—(See opposite page for legend).

sembles *Tetrahoplites*, and if found isolated could be distinguished from that genus only by the passage of the umbilical bullae into radially elongated bulges and the fading of the ribs from the middle of the sides. Compare, for instance, the lateral aspect of *Tetrahoplites sexangulatus* (Sinzow) (1907, pl. iii, fig. 4) with the paratype fragment of *F. farnhamensis* illustrated in Fig. 7.

Occurrence.—Coxbridge pit, Alton Road, west of Farnham, Surrey, southeast England. Horizon as for genus. Holotype (G.S.G.B. no. 74128), paratype 1 (G.S.G.B. no. 85850), paratype 2 (G.S.G.B. no. 85848), paratype 3 (G.S.G.B. no. 85849), collected by the author; paratype 4 collected by C. W. Wright and E. V. Wright.

Puzosigella, n. gen.

Fairly evolute, subdiscoidal, strongly costate. Whorl-sides flattened, subparallel. Venter broadly rounded. Umbilicus with subvertical wall and distinct rim, surmounted, in the early whorls, by obtuse bullae, from which the sigmoidal ribs take origin in bundles. Ribs later tending to differentiate into (long) primaries and (short) secondaries, the latter either free-ending or branching from the primaries at or below the middle of the sides. All ribs broadening slightly and fading on the venter, which they traverse in a forwardly directed arc. Inner lateral area tending to smoothness at large diameters. Periodic narrow constrictions, not persistent to the adult. Suture line puzosoid.

Type species.—*Pachydiscus sacramenticus* Anderson (1902: 105, pl. 6, figs. 133, 134; pl. 10, fig. 195), Horsetown group, Shasta County, Calif.

Remarks.—*Puzosigella* includes the following species from the Hulen Beds of the Horsetown group of California which were assigned to *Sonneratia* by Anderson (1938: 193–197): *P. sacramenticus*, *S. mulleri*, *S. taffi*, Anderson spp., and *S. rogersi* Hall and Ambrose. It is distinguished from *Sonneratia* chiefly by its flattened, less convergent sides, distinct umbilical rim, narrower and closer ribbing, relatively smooth venter, and the constricted early whorls. In whorl-shape, suture-line, and constrictions *Puzosigella* recalls the desmoceratid *Puzosia*.

Sonneratia, it may be added, has not yet been found in North America. Approximate contemporaniety of *Puzosigella* and *Sonneratia* is suggested by the records of *Douvilléiceras* of the *mammillatum* group above and below the horizon of *Puzosigella* (Anderson, 1938: 67–69), though the earlier occurrence of *Douvilléiceras* has not been illustrated and requires confirmation. The Texan and Colombian forms identified with *Sonneratia* and *Pseudosonneratia* by Scott (1937, 1940) and considered to indicate a Middle Albian age, are Upper Aptian Parahoplitidae and, so far as they are generically recognisable, belong to *Kasanskyella* and *Colombiceras*.

Occurrence.—LeConte and Perrin zones of the Hulen beds (Horsetown group) of California. Probably upper Lower Albian.

Leconteites (Breistroffer, 1952), n. gen.

This genus, proposed by Breistroffer[3] (1952: 266) without diagnosis and therefore hitherto invalid, comprises the Californian "*Cleoniceras*" of Anderson (1938). It occurs with early forms of *Puzosigella* and differs from that genus in its greater involution and compression, finer ribbing, more delicate and less persistent umbilical tubercles, tendency to smoothness in the adult, and in the presence of periodic desmoceratidlike peripheral ridges. Constrictions, if ever present, disappear before the neanic stage. There is no ventral acuteness as in *Cleoniceras* and the ribbing is sharper and more elegant than in that genus.

Type species.—*Desmoceras lecontei* Anderson (1902: 95, pl. 3, figs. 94, 95; pl. 10, fig. 190), Horsetown group, Shasta County, Calif.

Occurrence.—LeConte zone of the Hulen beds (Horsetown group) of California. Probably Lower Albian.

Tetrahoplitoides, n. n. (= *Coloboceras* Crickmay, 1927, *non* Trouessart 1889)

Cleoniceratinae resembling a compressed *Tetrahoplites*, but with more angular, less strongly ribbed venter, and with a potentiality for losing costation at the middle of the sides and the siphonal area. Suture-line simplified, with deep, subsymmetrical, trifid first lateral lobe.

Type species.—*Sonneratia stantoni* Anderson, (1902: 105, pl. 3, figs. 91–93; pl. 10, fig. 108), Horsetown group, Shasta County, Calif.

Remarks.—Of the numerous Horsetown forms referred to *Sonneratia* by Anderson, only *S. stantoni* and its ally *S. crossi* show a close ap-

[3] During the past few years this author has proposed numerous genera and subgenera of ammonites under conditions which do not meet the requirements of the International Rules of Zoological Nomenclature, often with citation of type species only.

proach to the Cleoniceratinae of the Eastern Hemisphere. Comparison is suggested with the Transcaspian group of *Tetrahoplites orientalis* Casey (e.g. Sinzow, 1907, pl. iii, figs. 9, 10, 18) and it is interesting to note that loss of ribbing as in *T. crossi* (Anderson) can be matched in species of *Farnhamia*, a forerunner of *Tetrahoplites*. There is also resemblance to the boreal genus *Gastroplites*, but in that genus the umbilical terminations of the ribs are not distinctly bullate as in *Tetrahoplitoides*. Moreover, the ontogenetic changes in the venter of *Gastroplites*—from smooth to an ornament of thick bar-like ribs—is the opposite of that of *T. stantoni*. In that species the ribs are continuous across the venter already at 15 mm. diameter and progressively weaken on the siphonal area as growth proceeds, so that finally they are in high relief only on the ventrolateral angles.[4] The wide, asymmetric principal lobe and pseudoceratitic tendency of the *Gastroplites* suture line is also distinctive.

Occurrence.—Upper part of Horsetown Group, Shasta County, Calif. Probably upper Lower Albian.

Subfamily Gastroplitinae Wright

Besides *Gastroplites* and *Neogastroplites* McLearn, this subfamily is here taken to include *Arcthoplites* Spath and *Subarcthoplites*, n. gen. It is regarded as an independent boreal offshoot of the Hoplitidae whose connection with the fundamental Desmoceratidae is suggested by *Cymahoplites*. It diverged from the normal evolutionary path of the Hoplitidae by strengthening rather than weakening the ornament along the siphonal line, and by acquiring tubercles only at a late phylogenetic stage.

Subarcthoplites, n. gen.

Like *Arcthoplites*, but with more convex venter, the ribs bifurcating from a lower point on the flanks and without the pronounced tendency to cupid's-bow curvature. Umbilical wall subvertical, fairly high, with rounded rim. Suture line as in *Arcthoplites*.

Type species.—*Lemuroceras belli* McLearn (1945: 10, pl. iii, figs 17–18), Loon River formation, Loon River, Buffalo Head Hill, Alberta, Canada.

Remarks.—*Subarcthoplites* is a welcome addition to our scanty knowledge of the boreal Albian ammonite fauna. It is important because it is linked, on the one hand, with *Arcthoplites* and, on the other, with *Cymahoplites*, a desmoceratid derivative known as yet only by its type species, *Ammonites kerenskianus* Bogoslowsky, from the Albian of Central Russia. McLearn's original determination of *S. belli* as *Arcthoplites* ? (see Spath, 1942: 688) was justified, and it is unfortunate that he and his compatriots subsequently followed Spath (1942: 688) in assigning this species and certain of its associates to *Lemuroceras*. This latter genus has been described otherwise only from India and Madagascar and its record from the Arctic Province, though unknown from the intervening areas, rightly puzzled Collignon (1949: 117). It is a more planulate form than *Subarcthoplites*, with an oblique, generally rimless umbilical wall. Definite bifurcation of the ribs is much less frequent than in the Canadian genus; moreover, the manner in which the ribs issue almost tangentially from the umbilicus and then abruptly change direction on the flank gives a distinctive appearance to *Lemuroceras*. In *S. belli* there is frequent bifurcation of the ribs from near the middle of the sides, and on the last half whorl of the holotype the primary stems are directed radially from the umbilicus, producing, with bifurcation, the Y-shaped pattern of *Arcthoplites*. It is this difference in the umbilical portion of the ribs which chiefly distinguishes *Cymahoplites* from *Lemuroceras*. These two genera are closely allied, however, and some approach to the *Cymahoplites* condition of ribbing is seen in *Lemuroceras besairiei* Collignon.

McLearn's "*Lemuroceras* cf. *indicum* Spath" and certain other fragments figured as *Gastroplites* by Warren (1947, pl. 29, figs. 8, 9, 11) are here provisionally referred to *Subarcthoplites*. "*Lemuroceras*" *macconnelli* (Whiteaves) and "*L*". *irene* McLearn are at present impossible to place, but comparison of casts of these species with a large series of *Lemuroceras* from India and Madagascar (kindly made available by Dr. L. F. Spath) does not support their reference to that genus. It has been pointed out previously (Casey 1952) that the European and Eurasian forms that have been identified with *Arcthoplites* belong to different genera (*Tetrahoplites* and *Protohoplites*).

In Greenland and Central Russia *Arcthoplites* is part of a Lower or basal Middle Albian faunal assemblage (Nikitin, 1888: 171–6; Spath 1946: 9), as also is *Cymahoplites* (Bogoslowsky, 1902:

[4] These ventrolateral portions of the ribs were described as bullae by Crickmay (1927: 511).

129). It may be surmised, therefore, that *Subarcthoplites* is of about the same date. This is supported by its occurence below the *Gastroplites* horizon (McLearn, 1945), the position of the *Gastroplites* fauna in the European zonal scheme having been fixed by the fortunate discovery of that genus in the topmost Middle Albian of Folkestone, south-east England (Casey, 1936: 448; Spath 1937).

Occurrence.—Western interior of Canada. Probably Lower or basal Middle Albian.

Subfamily Hoplitinae s.s.

Genus **Hoplites** Neumayr, 1875

The author supports the application of Wright (1951) to the International Commission on Zoological Nomenclature for use of its plenary powers to preserve the name *Hoplites*, Neumayr, 1875, for the genus of ammonites typified by *Ammonites dentatus* J. Sowerby. It is a polyphyletic genus, derived in part from *Pseudosonneratia* and in part from *Otohoplites*.

Isohoplites, n. subgen.

Like *Pseudosonneratia*, but with a ventral depression which attenuates or effaces the ribs along the siphonal line.

Type species.—*Parahoplites steinmanni* Jacob (1907: 312) (= *Ammonites interruptus* Pictet and Campriche, *pars* (1860, pl. xxviii, figs. 7–8 only), Albian, Sainte Croix, Switzerland.

Remarks.—*Isohoplites* lies on the border-line of the Cleoniceratinae and the Hoplitinae, being morphologically intermediate between *Pseudosonneratia* and *Hoplites* of the *dentatus* group. In the latter genus not only does the ventral depression or channel clearly separate the ribs, but the free ends of the ribs alternate on opposite sides of the venter and tend to become tuberculated. On a summation of morphological characters *I. steinmanni* is thus closer to *Pseudosonneratia*, but since the appearance of a ventral depression is taken as diagnostic of the Hoplitinae the subgenus is assigned to *Hoplites*.

Attention was called to the presence in the English Gault of this transitional group of hoplitids when some species were recorded as "Cf. *Pseudosonneratia laffrayei* Breistroffer" (Casey, 1950: 293). It is now known to be represented by a number of undescribed species of wide distribution in the basal Middle Albian of southeast England, where it is restricted to a narrow band immediately below the *Hoplites benettianus* subzone of the *Hoplites dentatus* zone and above the horizon of *Pseudosonneratia* (*Douvilléiceras mammillatum* zone). It is thus a subgenus of stratigraphical utility.

Occurrence.—Southeast England, France, Switzerland. Middle Albian (base of *H. dentatus* zone).

Family Desmoceratidae Zittel

Brewericeras, n. gen.

Discoidal, moderately involute Desmoceratidae resembling *Beudanticeras*, but with very flat, subparallel whorl-sides, consistently sharp umbilical rim, and no constrictions or peripheral ridges. Costate developments with falciform ribs on the upper lateral area that are sharper and more regular than those of *Beudanticeras* and which weaken on the ventral area.

Type species.—*Ammonites breweri* Gabb (1869: 130, pl. 20, fig. 5; pl. 19, fig. 5b), Horsetown group, Shasta County, Calif.

Remarks.—*Ammonites breweri* Gabb and its allies have been generally included in *Beudanticeras* or *Desmoceras*. The general aspect is that of a *Beudanticeras*, but in the costate forms of that genus (e.g. *B. dupinianum* d'Orbigny sp., *B. subparandieri* Spath) the ribs are as pronounced on the venter as on the sides, and the constrictions and accompanying ridges give an irregularity to the ornament which is quite distinct from that of *Brewericeras*. But whereas the costate species of *Beudanticeras* and *Brewericeras* are easily separable, the two genera produce smooth homoeomorphs (e.g. *Brewericeras haydeni* Gabb sp., *Br. hulenense* Anderson sp., and *Beudanticeras laevigatum* J. de C. Sowerby sp.). The whorl-section of the European *Beudanticeras*, however, is never so slab-sided as that of *Brewericeras*, and a sharp umbilical rim, while occasionally developed (as in *Beudanticeras sanctae-crucis* Bonarelli and Nagera), is not typical.

Occurrence.—North America. Lower and/or Middle Albian.

Zürcherella, n. gen.

Costate desmoceratids differing from *Uhligella* in their finer, puzosid ribbing, which tends to effacement around the umbilicus.

Type species.—*Desmoceras zürcheri* Jacob (*in* Jacob and Tobler, 1906; 9–10, pl. ii, figs. 1–3), Upper Aptian, Luitere Zug, Switzerland.

Remarks.—This typically Upper Aptian genus

(examples *D. zürcheri* Jacob, *D. stremmei* Zwierzycki, *Uhligella subzürcheri* Renngarten) is taken to embrace the Upper Barremian-Aptian group of *Desmoceras seguenzae* (Coquand) Sayn. Its separation from Jacob's comprehensive *Uhligella* was advocated in 1949 (Casey 1949: 338). A somewhat similar type of lateral ribbing is produced in the more inflated *Valdedorsella*.

Occurrence.—North-west Europe, Russia, North and East Africa, South America. Upper Barremian-Upper Aptian.

Family Cheloniceratidae Spath

Genus **Cheloniceras** Hyatt, 1903

Notwithstanding the somewhat unusual circumstances of its introduction (Stanton, *in* Hyatt, 1903: 101, footnote), the genus *Cheloniceras*, with authorship credited to Hyatt and with *Ammonites royerianus* d'Orbigny as type species, has been universally accepted by ammonite specialists. Nomenclatorial stability of the genus is threatened, however, by inability to assess satisfactorily the taxonomic characters of its type species.

D'Orbigny's holograph of *Ammonites royerianus* illustrates an immature ammonite from the Aptian of Bailly-aux-Forges, Wassy (Haute-Marne), France, which is stated (d'Orbigny, 1841: 365–366) to be 12 mm. in diameter and to be represented in natural size. As noted by Stoyanow (1949: 104), however, the illustration is of 20 mm diameter. In any case, the specimen is too small for positive determination below family level. Kilian (1913: 340) referred it to the same group as *A. ricordeanus* d'Orbigny (now assigned to the genus *Megatyloceras* Humphrey), while Rodighiero (1922: 63, 67, 69) even supposed it to belong to *Astiericeras*. On the other hand, Nikchitch (1915: 3, 4, 13, 50) asserted that *A. royerianus* is merely the young of *A. cornuelianus* d'Orbigny, the type of which was obtained from the same area and from the same stratigraphical horizon. Efforts to trace the original specimen (or specimens) on which *A. royerianus* was based have been unsuccessful, and in view of the similarities in the nuclei of species of *Cheloniceras*, *Epicheloniceras* n. subgen., *Megatyloceras* and *Roloboceras* n. gen., its identification with *Ammonites cornuelinanus* cannot be considered beyond doubt.

It is clear that so long as *Ammonites royerianus* d'Orbigny remains the type species of *Cheloniceras*, the nomenclature of that genus and of the family Cheloniceratidae in general rests on an insecure basis. In order to remove this insecurity and to validate existing nomenclatorial practice, the author, in conjunction with C. W. Wright, has applied to the International Commission on Zoological Nomenclature to use its plenary powers to set aside all previous type designations for the genus *Cheloniceras* and to designate *Ammonites cornuelianus* d'Orbigny to be type species of that genus.

The interpretation of *Cheloniceras* s.s. here adopted complies with the acceptance of *A. cornuelianus* d'Orbigny as the type species. This is a laterally bi-tuberculate form whose flat venter is angulated at the margins but does not bear tubercles.

Epicheloniceras, n. subg.

Cheloniceras in which the primary ribs (and occasionally the secondary ribs) are attenuated or depressed along the middle of the venter and are elevated into tubercles at the ventro-lateral angles. At large diameters whorls rounded and with close, untuberculated ribs, as in *Cheloniceras* s.s. of similar growth stage.

Type species.—Douvilléiceras tschernyschewi Sinzow (1906: 182–186, pl. ii, figs. 11, a, b, c, (lectotype), 12; pl. iii, figs. 2–7), Upper Aptian, Kysil-Kaspak (Kislowodsk), Russia.

Remarks. — This subgenus, corresponding broadly to the "group of *Douvilléiceras martini*" of authors, had an almost world-wide distribution in Upper Aptian times. *Ch. orientale* (Jacob), *Ch. tschernyschewi* (Sinzow), *Ch. subnodosocostatum* (Sinzow), *Ch. caucasicum* (Anthula), and *Ch. stoliczkanum* (Gabb) are some of the more familiar species. Unfortunately d'Orbigny's *Ammonites martini* (d'Orbigny, 1841, pl. 48, figs. 7–10), though widely quoted, is unsuitable as type species since it has a confused taxonomic history and cannot be correctly interpreted from the idealised and inadequate protographs.

Epicheloniceras was derived directly from *Cheloniceras* s.s. of the Lower Aptian by differentiation of the ventral ribbing. Records of species of *Epicheloniceras* in the Lower Aptian (e.g. Kilian, 1915: 62–63; Roch, 1927: 21–22) are based on misidentifications.

The type species of *Epicheloniceras* has been fully studied by Nikchitch (1915: 25–37, Russian text).

Occurrence.—Northwest Europe, Russia,

Africa, South America, Mexico, California. Upper Aptian.

Roloboceras, n. gen.

Cheloniceratidae with depressed, semicircular whorl-section and thick, blunt ribs which pass over the venter without modification and which tend to unite at the umbilical border in obtuse nodes or bulges. Irregularly ribbed and constricted juvenile stage often prolonged. Umbilical wall high, subvertical and smooth. Suture line simplified, with massive external saddle, low lateral saddles and very narrow lateral lobes.

Type species.—*Ammonites hambrovi* Forbes (1845: 354, pl. xiii, fig. 4), Lower Greensand (Lower Aptian), Atherfield, Isle of Wight.

Remarks.—In whorl-shape and tuberculation (recalling certain Turonian Vascoceratidae) *A. hambrovi* and its allies stand apart from other Cheloniceratidae and the group clearly requires generic separation. The genus *Megatyloceras* was founded by Humphrey (1949: 149) to include forms previously referred to the "group of *Douvilléiceras hambrovi* (Forbes)", but with *Douvilléiceras coronatum* Rouchadzé as type. As interpreted by its type species, *Megatyloceras* must be restricted to those species which show exaggerated lateral tubercles placed at the middle of the side, giving a coronate whorl-section. Of the species listed by Humphrey, *Megatyloceras* thus embraces only *D. coronatum* Rouchadzé, *Megatyloceras georgiense*, n. n.,[5] and, probably, the miniature *Ammonites ricordeanus* d'Orbigny.

Roloboceras includes *A. hambrovi* Forbes, *Cheloniceras hambrovi* var. *horrida* Spath, *Ch. perli* Spath, and a number of undescribed species in the English Lower Greensand.

Occurrence.—Northwest Europe. Lower Aptian (*Deshayesites deshayesi* zone).

Family Parahoplitidae Spath

Subfamily Acanthohoplitinae Stoyanow

Gargasiceras, n. gen.

More or less evolute Acanthohoplitinae. Whorl-sides and venter flattened; umbilical and ventral margins rounded. Ribs straight or slightly flexed, attenuated on the sides, tending to broaden and become flat-topped on the venter. Primary ribs on the inner whorls periodically emphasized or forming thin lateral flanges which are limited ventrad by the line of involution. Secondary ribs intercalated or branching from the top of a primary flange, the point of bifurcation marked by a minute tubercle. Ribbing later becoming more uniform, without tubercles, flanges or bifurcation. Neanic whorls with a narrow depression along the siphonal line. Suture line as in *Colombiceras*.

Type species.—*Ammonites gargasensis* d'Orbigny (1841: 199–200, pl. 59, figs. 5–7), Upper Aptian (Gargasian), Gargas (Vaucluse), France.

Remarks.—Species of *Gargasiceras*, appearing already in the Lower Gargasian ("*martini* zone"), have been assigned usually to the genus *Acanthohoplites* Sinzow, but the *aschiltaensis* group of Anthula, to which Sinzow's genus must be restricted, is of later horizon and comprises less evolute forms with rounder whorls, no ventral depression and a different style of ribbing. The affinities of *Gargasiceras* lie wholly with the contemporaneous *Colombiceras*. In that genus, however, the propensity for flat-topped ribbing extends to the whorl-sides, and the ventral groove and lateral flanges of the young *Gargasiceras* are not present. As in the Acanthohoplitinae generally, the tuberculate stage is transient and may be terminated very early in ontogeny (e.g. *Gargasiceras interiectum* Riedel sp.).

In addition to the type species, the following forms of *Gargasiceras* have been noted: *G. aptiense* (Roch), *G. recticostatum* (Kilian) Roch sp., *G. attenuatum* (Kilian) Roch sp. (Roch, 1926, *sub Acanthoplites*), *G. acutecostum* (Riedel), *G. interiectum* (Riedel) and *G. pulcher* (Riedel) (Riedel, 1937, *sub Acanthoplites*).

Occurrence.—Southeast France, South America, Mexico.

[5] = *Douvilleiceras coronatum* Rouchadzé, 1938 (:178–179, pl. i, fig. 7; pl. ii, fig. 1). Differs from *D. coronatum* Rouchadzé, 1933 (:195–197, pl. iii, fig. 4) in the persistence of the lateral tubercle.

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BOTANY.—Setaria: *Fascicle organization in four species.*[1] ERNEST R. SOHNS, U. S. National Museum. (Communicated by Jason R. Swallen.)

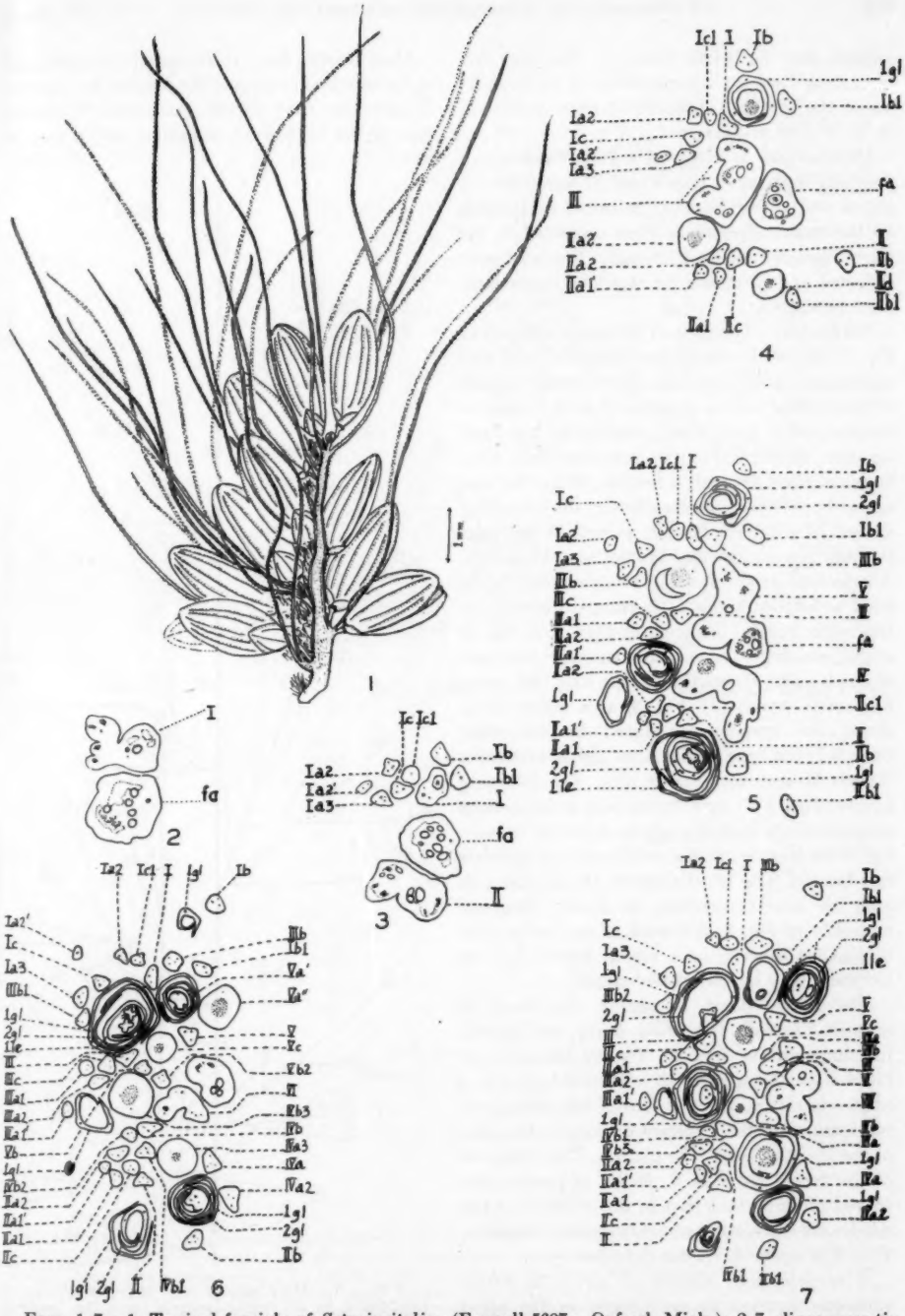
Setaria, a genus of grasses of 100 or more species, is widely distributed in the tropics, subtropics, and temperate regions of the world. Several species are cultivated for ornament; one species (*S. italica*) has been cultivated for food for many centuries and some annual species, especially in the temperate regions of the world, are serious weeds (Bews, 1929; Hitchcock, 1936; Pilger, 1940). Nine species are native in the United States and 13 species have been introduced, 4 of which are cultivated as forage or ornamental grasses (Hitchcock, 1951).

The inflorescence of the species varies from densely spikelike and many-flowered to open and few-flowered. The inflorescence, which is a terminal panicle, is composed of numerous fascicles. Each fascicle contains one or more spikelets and from one to numerous sterile branches (bristles). The sterile branches are persistent on the axis of the fascicle. The fascicle varies in complexity from that of *S. italica*, in which there are numerous spikelets and sterile branches to that of *S. palmifolia* in which there is a spikelet and, occasionally, a single bristle.

The fascicles of several species of *Setaria* have been studied for bristle formation, for the presence or absence of an axis terminus and for the determination of sterile and fertile axes. This study, involving four species of *Setaria*, is concerned with the organization and interpretation of the fascicle as the basic unit of the inflorescence.

Historical.—Goebel (1884), who investigated bristle formation in *S. glauca* and *S. italica*, found that the tip of the inflorescence axis was sterile and prolonged as a bristle. Branching of the fascicle was interpreted as dorsiventral and two-ranked. Only the axes of the second order produced spikelets; the others remained sterile (bristles). Goebel diagrammed the branching of the fascicle in *S. viridis* (see his figure 18). The relationship of first-order branches is not clear, and there is no indication of fertile axes in the diagram. Goebel used entire young fascicles and based his observations on macroscopic examination. He failed to find support for Hofmeister's contention that spikelet formation was initiated on some bristles only later to cease development and fall off. Goebel found the spikelets of *S. italica* and *S. glauca* to contain two florets; the lower staminate or aborted and the upper hermaphrodite. The upper floret, according to Goebel, originated near the axis terminus. The designation of the axis terminus in his drawings (see his figures 11 and 12) is, as Schumann (1890) pointed out, undoubtedly a misinterpretation. Goebel stated that the florets (Blüthe) appear to develop in a terminal position. He observed that the bristles are persistent; that their numbers are variable and that their presence helps prevent the birds from picking the seeds out of the spikelets. Goebel also examined *Pennisetum verticillatum* R. Br. (= *Setaria verticillata* (L.) Beauv.) and concluded that the fascicle of this species was a perfected fascicle of *Setaria*. *S. italica* and *S. glauca* were studied by Schuster (1910). He reviewed the work of Goebel and Schumann and asserted that he found an axis terminus in the upper floret (. . . in der oberen Blüthe einen deutlichen Achsenhöcker hatten . . .) of both species. *Pennisetum verticillatum* R. Br. (= *Setaria verticillata* (L.) Beauv.) was found to have no axis terminus and he agreed with Goebel that "only the ends of axes of second order were fertile, while the bristle-involucre was formed from the remaining sterile lateral branches." Arber (1931) showed that the fascicles of *S. glauca* usually have one spikelet, the lower floret of which is aborted and the upper is perfect. She regards the median spikelet as terminating the axis of the fascicle. It is concluded that "each ultimate-shoot—not each individual bristle—is equivalent to a spikelet." The bristles may be interpreted either as leaf or stem structures; however, it is concluded that the bristles are to be regarded as stems because they "play the part of axes in relation to lateral members; and also because the axis of an abortive

[1] Based on part of a thesis, "The Floral Morphology of *Cenchrus*, *Pennisetum*, *Setaria*, and *Ixophorus*," submitted to the faculty of the Graduate School of Indiana University in partial fulfillment of the requirements for the degree doctor of philosophy. The writer is grateful to Dr. Paul Weatherwax for suggesting the problem and for helpful suggestions throughout the investigation.



FIGS. 1–7.—1, Typical fascicle of *Setaria italica* (Farwell 5607a, Oxford, Mich.); 2–7, diagrammatic transsections of a fascicle of *S. italica*. (*fa*—fascicle axis; *1 gl*—first glume; *2 gl*—second glume; *1 le*—lemma of the lower floret; *2 le*—lemma of the upper floret; *I, II, III*, etc.—first-order branch; *a, b, c*, etc.—second-order branch; *a* 1, *b* 1, *c* 1, etc.—third-order branch; *a* 1′, *b* 1′, *c* 1′, etc.—fourth-order branch; *a′* and *a″*—two branches of equal rank. All figures approximately ×25.)

spikelet may be bristle like . . .." She does not agree with Goebel's interpretation of the branching of the fascicle. These views were reaffirmed in her studies in 1934.

Materials and Methods.—Dr. Paul Weatherwax provided seeds of *S. italica* and *S. palmifolia*. *S. glauca* and *S. viridis* were collected in Indiana by the writer. Specimens were deposited in the Herbarium of Indiana University. Fascicles were collected and processed by standard methods in microtechnique.

Discussion.—A fascicle of *S. italica* is shown in Fig. 1. It has a central axis (fascicle axis) and numerous lateral branches. Each lateral branch of the central axis is designated as a branch of the first-order, from which arise lateral members (second-, third-, and fourth-order branches, etc.). Serial sections through a fascicle, from the base upwards, provide a means whereby the branching system of a typical fascicle as well as the relationship of spikelets and bristles may be shown. A selected series of such transsections, taken from a detailed series of drawings prepared by the writer (1949), is shown in Figs. 2–7. Fig. 2, a diagrammatic transsection through the base of the fascicle, shows the fascicle axis (*fa*) and a first-order branch (*I*). Fig. 3, at a higher level, shows the branches produced by first-order branch I, the base of the next higher first-order branch II and the fascicle axis. The following figures (Figs. 4–7) were drawn from serial sections at successively higher levels to show the branching of the fascicle and the relationship of spikelets and bristles. The relationship of the fascicle axis and its lateral members is shown diagrammatically in Fig. 8. A branch of any order may be spikelet-bearing, or a lateral branch and its members may be completely sterile.

The upper floret is readily deciduous at maturity leaving the lower floret and glumes remaining in the fascicle. The abcission of the floret from the spikelet of a Panicoid grass is a relatively rare occurrence. One of the distinguishing features of the Panicoid grasses is abscission of the spikelet below the glumes. The abscission of the fertile floret in *S. italica* unquestionably played an important part in the selection of this species for cultivation and subsequent domestication. The upper floret has lodicules.

A fascicle may contain as many as fifteen spikelets. Apparently only those in the upper part of the fascicle are fertile since the number of caryopses ranged from two to five (*S. italica*).

Most bristles have three vascular bundles and in the terminal portion of the bristles the vascular bundles may have sheaths. Among the epidermal cells of the bristles an occasional stoma may be found.

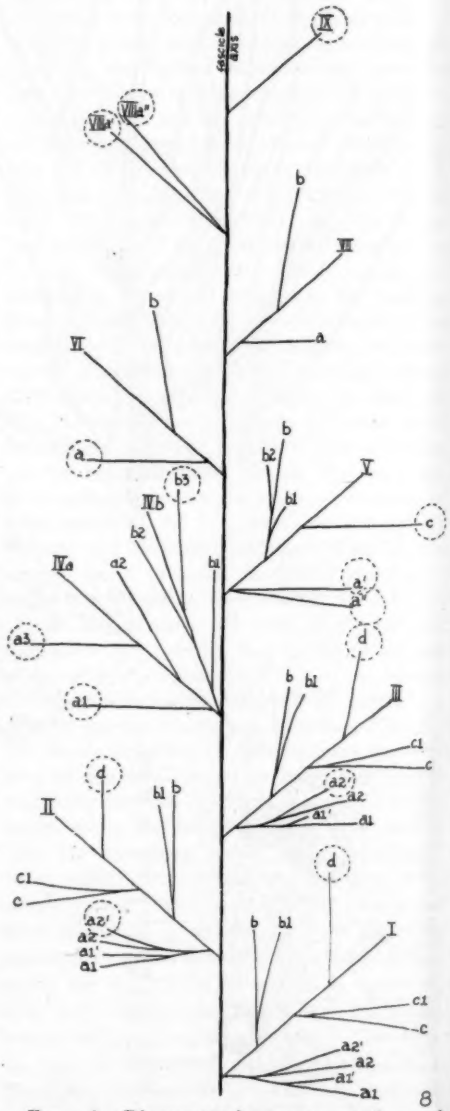
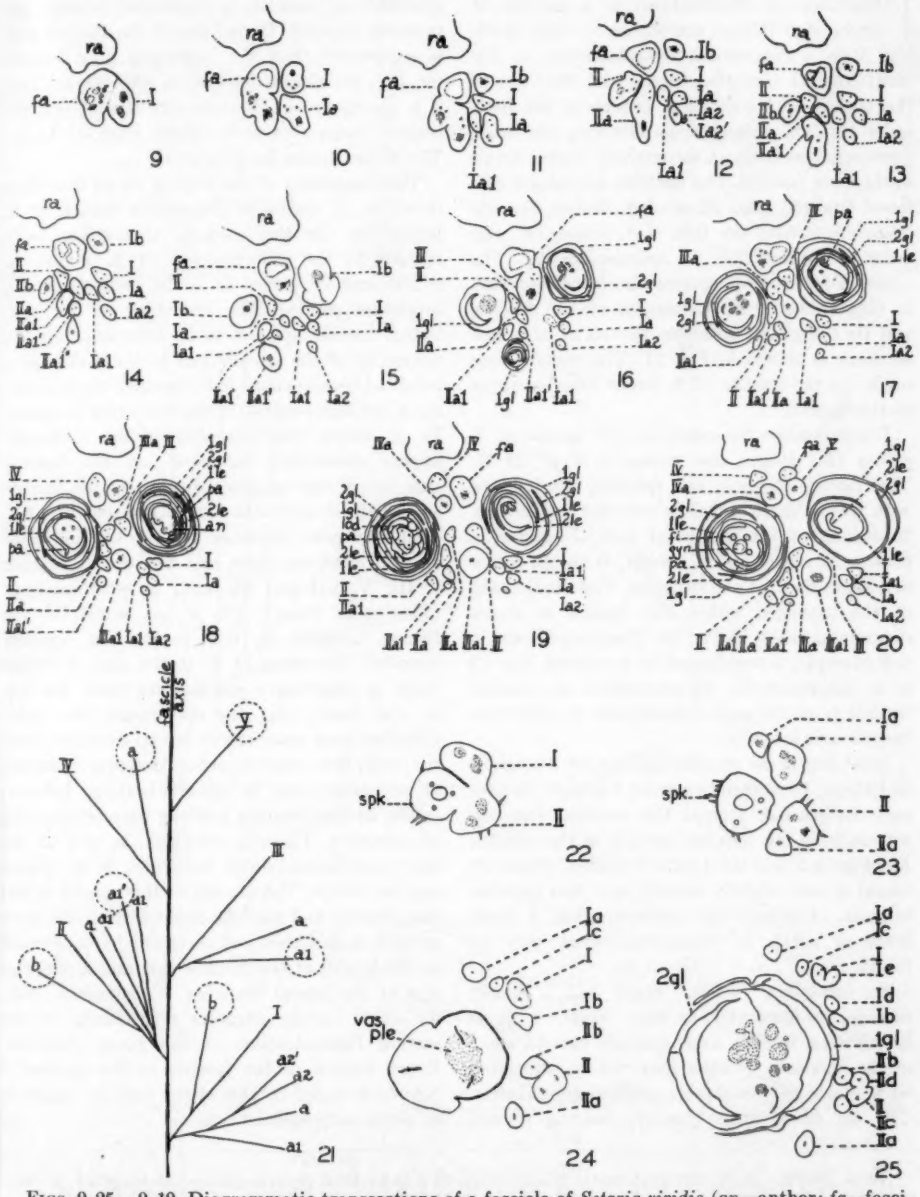


FIG. 8.—Diagrammatic representation of branching in a typical fascicle from the inflorescence of *Setaria italica* as constructed from serial transsections. Dotted circles at ends of branches represent spikelets.



FIGS. 9–25.—9–19, Diagrammatic transsections of a fascicle of *Setaria viridis* (*an*—anther; *fa*—fascicle; *fi*—filament; *1 gl*—first glume; *2 gl*—second glume; *gyn*—gynoecium; *1 le*—lemma of the lower floret; *2 le*—lemma of the upper floret; *lod*—lodicule; *pa*—palea; *ra*—rachis of the inflorescence; *I, II, III*, etc.—first-order branch; *a, b, c*, etc.—second-order branch; *a* 1, *b* 1, *c* 1, etc.—third-order branch; *a* 1′, *b* 1′, *c* 1′, etc.—fourth-order branch); 20, diagrammatic representation of fascicle branching based on serial transsections, dotted circles at ends of branches representing spikelets; 21–25, diagrammatic transsections of a fascicle of *Setaria glauca*. (Symbols as above plus *spk*—spikelet; *vas ple*—vascular plexus. All figures approximately ×25.)

Diagrammatic transsections of a fascicle of *S. viridis* (L.) Beauv. are shown in Figs. 9–20. Fig. 9 is a diagrammatic transsection of the rachis (*ra*) of the inflorescence and the base of the fascicle (*fa*) showing a branch of the first-order (*I*). The transsections following are made from serial sections at successively higher levels in the same fascicle. The fascicles are smaller and fewer flowered than those of *S. italica*. Fascicle branching is also like that of *S. italica*, i.e., any order of branch may be spikelet-bearing. The upper florets in this species also have lodicules. A diagrammatic representation of the fascicle and its branches, based on this series of transsections, is shown in Fig. 21. The observations made for the bristles of *S. italica* likewise apply to this species.

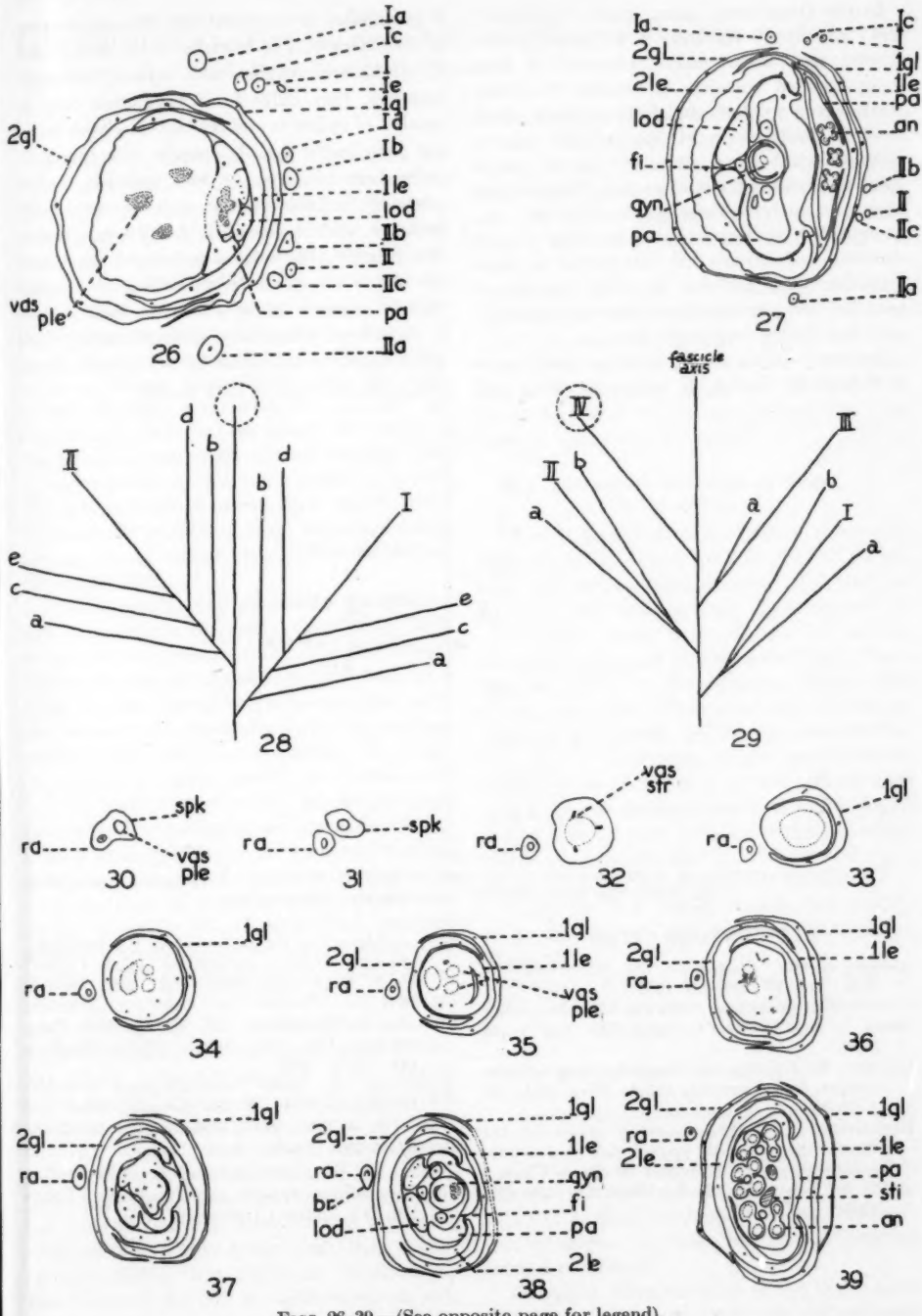
Diagrammatic transsections of a fascicle of *S. glauca* (L.) Beauv. are shown in Figs. 22–27. This fascicle has only one spikelet, but fascicles with two or three spikelets were not uncommon. Branching of the first-order axes is similar to that in *S. italica* and *S. viridis*. Both the upper and lower florets have lodicules. The relationship of the branches within the fascicle is shown diagrammatically in Fig. 28. The fascicle axis, in this example, is terminated by a spikelet. Fig. 29 is a diagrammatic representation of another fascicle from the same inflorescence in which the fascicle axis is sterile.

Most first-order branches, which are triangular in outline, have three vascular bundles. Sheaths may be present around the vascular bundles, especially in the terminal portion of the bristles. Most second- and third-order branches, which are round or only slightly angled, have two vascular bundles. Although the epidermis has a thick layer of cutin, an occasional stoma may be found.

S. palmifolia (Willd.) Stapf has a simple fascicle, as illustrated in Figs. 30–38. A single bristle (the fascicle axis) extends beyond some of the spikelets. Bristles may not be associated with many of the shortly pedicellate spikelets. The tip of a lateral branch, bearing several spikelets or fascicles, is prolonged beyond the terminal spikelet. Branching of the fascicle axis is suppressed, but the beginning of a branch (*br*, Fig. 38) can be detected in some axes. There is a divergence of the vascular strand, but the branch terminates as a slight ridge or bulge. The upper florets have lodicules.

The complexity of the fascicle varies from that shown in *S. italica* to the simple fascicle of *S. palmifolia*. On the basis of this study, each fascicle in the inflorescences of *S. italica*, *S. viridis* and *S. glauca* is to be compared to a miniature panicle. The branching of the individual fascicle appears to be alternate, but the proximity of the fascicle axis to the rachis (as a result of compression) has obscured the arrangement (probably spiral) of the first-order branches. In *S. italica*, the branches of the first-order appear alternately arranged on the fascicle axis, i.e., if one imagines the axis of the fascicle as a circle divided into four quadrants (Fig. 40), then first-order branches II, IV, VI, and VIII arise in quadrant three and first-order branches I, III, V, VII and IX occur in quadrant four. (First-order branch IX is not shown in the figures included in this paper). In complex fascicles, like those of *S. italica* and *S. viridis* there is progressive sterilization from the top to the base, i.e., the lowermost first-order branches have more sterile lateral members than the upper first-order branches. However, branches of any order may be spikelet-bearing. Inflorescences having complex fascicles may be regarded as primitive. The axis terminus, as well as the first- and second-order branches, in *S. glauca* may be fertile. The fascicle of this species is less complicated and may be derived from the type present in *S. italica* and *S. viridis* by a decrease in the length of the fascicle axis and a suppression of the lateral branches. *S. palmifolia*, with its single bristle, suggests relationship to the section *Paurochaetium* of the genus *Panicum*. Every branch of the fascicle in the species of *Setaria* included in this study may be regarded as potentially spikelet-bearing.

FIGS. 26–39.—26–27, Diagrammatic transsection of a fascicle of *Setaria glauca* (*an*—anther; *fi*—filament; *gyn*—gynoecium; *1 gl*—first glume; *2 gl*—second glume; *1 le*—lemma of the lower floret; *2 le*—lemma of the upper floret; *lod*—lodicule; *pa*—palea; *vas ple*—vascular plexus; *I*, *II*—first-order branch; *a*, *b*, etc.—second-order branch. Fig. 26 approximately ×25; Fig. 27 approximately ×18); 28–29, diagrammatic representations of fascicle branching based on serial transsections, dotted circles at ends of branches representing spikelets; 30–39, diagrammatic transsections of fascicle of *S. palmifolia* (abbreviations as for Figs. 26 and 27 plus *br*—rudimentary first-order branch; *ra*—rachis; *spk*—spikelet; *sti*—stigma). (All figures approximately ×25.)



FIGS. 26–39.—(See opposite page for legend).

In the Gramineae, among many "primitive" and "advanced" features, it is generally considered that evolutionary "advance" is from many-flowered spikelets in clusters to single, one-flowered spikelets and from spikelets which have a prolongation of the spikelet axis to spikelets which have one or two florets, one of these terminating the spikelet axis. These criteria appear to apply to these species of *Setaria*, i.e., complicated, complex fascicles consisting of many spikelets and bristles are interpreted as more primitive than fascicles in which the lateral branches are suppressed and the single spikelet, with two florets, terminates the axis.

Summary.—This study, based on four species of *Setaria* (*S. italica*, *S. viridis*, *S. glauca* and *S. palmifolia*), is concerned with the organization of the fascicle. The fascicles of *S. italica* and *S. viridis* are complex, with several first-order branches; they differ from each other only in number of spikelets and bristles. *S. glauca* has a less complicated fascicle, usually with two first-order branches, one or two spikelets, either produced on the fascicle axis or on lateral branches, and *S. palmifolia* has a single bristle (the fascicle axis) extending beyond some, but not all, of the spikelets. Branching of complex fascicles appears to be alternate. Each bristle is considered potentially spikelet-bearing. The upper florets in all species have lodicules and *S. glauca* has lodicules in both florets.

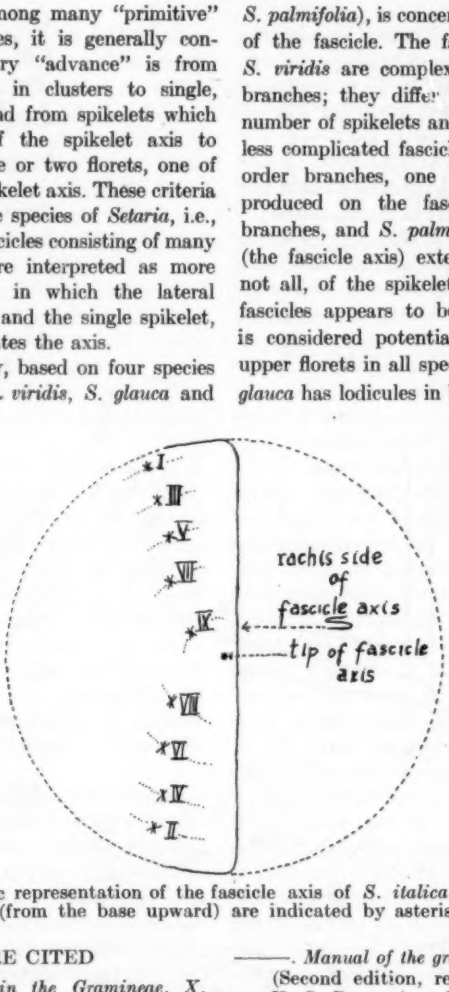


FIG. 40.—Diagrammatic representation of the fascicle axis of *S. italica*. First-order branches I–IX (from the base upward) are indicated by asterisks.

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ORNITHOLOGY.—*Five new races of bulbuls (Pycnonotidae) from southern Asia.* H. G. DEIGNAN, U. S. National Museum.

I

As early as 1943 Delacour (Zoologica **28:** 21) reduced *"Otocompsa flaviventris* (Tickell)" to conspecificity with *Pycnonotus gularis* of the Malabar Coast of western India. The present author in 1945 (U. S. Nat. Mus. Bull. **186:** 329), unwilling to follow him so far, nevertheless treated *flaviventris* as conspecific with *dispar* of Java. Now renewed study of the species, with previously unavailable material, convinces me that even Delacour did not go far enough and that to bring *all* forms of the group into a single species requires that *P. melanicterus* of Ceylon be also included. This unfortunately means that *melanicterus* becomes the nominate race, Gmelin's name having many years' priority over *dispar* Horsfield, 1820.

No characters are possessed by *gularis* and *melanicterus* to justify their being kept as one or two species distinct from *dispar-flaviventris*. Small dimensions and lack of a crest in these far-southern forms agree with the tendency in *dispar-flaviventris* to become smaller and show a reduction of crest-development from north to south (*cf. caecilii* and *dispar* with *flaviventris* and *vantynei*). The yellow gular area of *melanicterus* is analogous with the similarly colored gular area in the long-crested *montis*, a montane race of Borneo, and appears also in the juvenile of *johnsoni* (and perhaps others). The strawlike red throat feathers of *gularis* are matched in individuals of *johnsoni*, *auratus*, and *vantynei* and in all adults of *dispar*. *P. melanicterus* has the rectrices broadly white-tipped, while *gularis* has them narrowly tipped with cream; newly molted specimens of any population of *dispar-flaviventris* have these feathers narrowly tipped with white or yellowish white. (It may be noted that, in the closely related species *jocosus*, the race *fuscicaudatus* has narrow whitish tips to the rectrices, while *all* others have *broad* white tips, yet no one can doubt that these are conspecific.) The color of the iris in *melanicterus* is red, sometimes brown (immaturity?); in *gularis* and all forms of *dispar-flaviventris* the iris is yellow, sometimes brown (immaturity). (Here it may be pointed out that among races of *Pycnonotus simplex* the iris color may be white, cream, orange, or red, and among those of *P. plumosus* either yellow or red.)

Examination of new material recently collected in Thailand has shown that two more populations of this bulbul, left unnamed in an earlier revision (Deignan, Journ. Washington Acad. Sci. **38:** 245–248, 1948) may now be set up as subspecies. The first of these will be called—

Pycnonotus melanicterus elbeli,
n. subsp.

Type: U. S. Nat. Mus. no. 249038, adult male, collected on the island Ko Kut [lat. 11°40′ N., long. 102°35′ E.], Trat Province, Thailand, on December 25, 1914, by Cecil Boden Kloss.

Diagnosis: From both *johnsoni* of the adjacent mainland and *caecilii* of the Malay Peninsula, separable by the decidedly deeper color of the upper parts, which is an almost brownish olive green, without golden suffusion (darker than in any other form of the species known to me). From *caecilii* it is further differentiated by the greater development of the crest (equal to that found in more northern races) and rather longer wing (81–85 mm in 11 males of *elbeli*, against 78–82 mm in 10 males of *caecilii*).

Range: Ko Kut and Ko Chang, and possibly other Islands off the coast of southeastern Thailand.

Remarks: Named in honor of Robert E. Elbel, who has sent me valuable collections of birds from Thailand.

The second may be called—

Pycnonotus melanicterus negatus,
n. subsp.

Type: U. S. Nat. Mus. no. 450800, adult male, collected at Ban Hin Laem [lat. 14°40′ N., long. 98°40′ E.], Kanchanaburi Province, Thailand, on November 1, 1952, by H. G. Deignan; original number 45.

Diagnosis: With the color of the upper parts slightly darker and decidedly less suffused with

golden than in *xanthops* (northwestern Thailand), but lighter and more gold-suffused than in *caecilii* (Malay Peninsula), it is almost exactly intermediate between the hues shown by these two and about the same as in *auratus* (northeastern Thailand).

Development of crest and length of wing are as in *caecilii* (7 adults of *negatus* have the latter measurement 78–83 mm, while 17 of *caecilii* have it 77–82 mm); accordingly, easily differentiated from *xanthops* not only by color of the upper parts, but also by short crest and wing (20 adults of *xanthops* have the wing length 83–87 mm).

Range: Valley of the river Mae Klong, southwestern Thailand.

Remarks: Junge and Kooiman (Zool. Verh. [Leiden] **15:** 27–28. 1951) have referred four specimens from the vicinity of Ban Hin Laem to *caecilii*, with the comment that the differences between even *caecilii* and *xanthops* are slight. Since their examples of *xanthops* and true *caecilii* were *lent* them by me and now again lie before me, I can only repeat that they seem to me to differ conspicuously in size, development of crest, and color of upper parts.

Junge and Kooiman had but four specimens from the Mae Klong basin, collected between April 27 and May 27, and therefore dulled and darkened by wear; in my previous study (1948) I observed that "the effects of wear on the plumage are so marked that only fresh-plumaged specimens are suitable for taxonomic study." The series before me, taken between October 30 and November 12 agree in length of wing and crest with *caecilii*, but in color are much nearer *xanthops*; in the circumstances, they require a particular name.

II

Oberholser (U. S. Nat. Mus. Bull. **159:** 78. 1932) separated the white-eyed form of *Pycnonotus simplex* of the northern Natuna Islands from the red-eyed birds of the southern Natunas under the name *axanthizus* (which I consider, as did Chasen, synonymous with *halizonus*, 1917, based on birds from the Anamba Islands). To the red-eyed population he gave a name in manuscript but ended by combining them with *perplexus* Chasen and Boden Kloss (Journ. f. Orn., Ergänzungsb. 2, 1929: 116: British North Borneo), of which the entire diagnosis reads: "Like *simplex* of the Malay Peninsula but the irides crimson instead of white." Following Oberholser, Chasen (A Handlist of Malaysian Birds, 1935: 201) gave as the extended range of his *perplexus* "Borneo; South Natuna Islands; Billiton."

Many museum skins are without indication of eye color, but so far as this important information is available it shows that not all Bornean *simplex* have red irides. Red-eyed birds are known from Balambangan Island (type locality of *perplexus*), Rayoh (near Brunei Bay), Abai (on the Kinabatangan River), and Sarawak; on the other hand, birds collected by me in 1937 on the Kalabakang River (near Sibatik Island) had the irides cream. Moreover, two skins before me from Billiton Island and one from Bangka (whose birds are placed by Chasen with the white-eyed nominate race) had, like a series from the southern Natunas, the irides red.

The red-eyed Natuna birds are in fact not *perplexus* at all, and I intend to call them—

Pycnonotus simplex oblitus,
n. subsp.

Type: U. S. Nat. Mus. no. 174759, adult male, collected at Pulau Serasan, southern Natuna Islands, on June 3, 1900, by William L. Abbott.

Diagnosis: Differs from *P. s. halizonus* of the northern Natunas and the Anambas by having the irides red instead of white.

From *P. s. perplexus* of British North Borneo separable, exactly as is *halizonus*, by longer and heavier bill, and probably also by other measurements (which can not be given owing to the worn state of plumage shown by my series).

Range: Southern Natuna Islands; western Borneo; Billiton and Bangka Islands.

Remarks: Color distinctions relied upon by Oberholser in establishing his races seem to me due wholly to wear, and Chasen has concurred in this opinion. Only two skins from western Borneo (Sarawak) have been examined; in dimensions of bill they seem to stand nearer *oblitus* than topotypical *perplexus*. The few specimens seen from Bangka and Billiton cannot be separated from *oblitus*.

III

In a review of the races of *Microscelis charlottae* (Proc. Biol. Soc. Washington **61:** 6. 1948), I suggested that an unnamed form of the species would be found to exist in

southwestern Thailand. Specimens now before me show that this surmise was correct, and I name the new race—

Microscelis charlottae lekhakuni, n. subsp.

Type: U. S. Nat. Mus. no. 450792, adult female, collected at Ban Hin Laem [lat. 14°40′ N., long. 98°40′ E.], Kanchanaburi Province, Thailand, on November 16, 1952, by H. G. Deignan; original number 180.

Diagnosis: Readily separable from *M. ch. propinquus* (northwestern Thailand) and *M. ch. simulator* (southeastern Thailand) by having the upper parts brownish olive instead of olive-green, and by having the under parts grayer and less strongly washed with a paler yellow than in either of these two.

From *M. ch. cinnamomeoventris* (southern Tenasserim) distinguishable by the decidedly paler brownish olive of the upper parts and the more vivid yellow suffusion over the under parts and also by its shorter and lighter bill.

From *M. ch. innectens* (Cochin-China) separable by the decidedly lighter brownish olive of the upper parts (which, in *innectens*, are as dark as in *cinnamomeoventris*).

Wing length: 80, 82 mm (2 females), 80, 83 mm (2 unsexed), thus agreeing with *simulator* of the same latitudes in southeastern Thailand.

Range: Lowland evergreen forests of southwestern Thailand, north at least to lat. 16°10′ N., south to lat. 11°40′ N. (where intergrading with *cinnamomeoventris*); probably also the adjacent districts of Tenasserim.

Remarks: All of five specimens had the irides gray.

This form is named for my good friend and generous host in Bangkok, Bun Song Lekhakun, M.D. (also known as Boon Song Lekagul).

IV

The bulbul *Criniger ochraceus* has been reported from the forests of southwestern Thailand only by Meyer de Schauensee (Proc. Acad. Nat. Sci. Philadelphia **98:** 58. 1946), who listed three specimens from Khao Luang as of the nominate race (along with genuine *ochraceus* of peninsular Thailand south of the Isthmus of Kra and birds of southeastern Thailand [*recte cambodianus*]).

A series recently collected in southwestern Thailand show that the area is in fact inhabited by a well-marked form that connects *ochraceus* with *henrici* of northwestern Thailand; it may be called—

Criniger ochraceus crinitus, n. subsp.

Type: U. S. Nat. Mus. no. 450785, unsexed adult, collected at Ban Hin Laem [lat. 14°40′ N., long. 98°40′ E.], Kanchanaburi Province, Thailand, on November 17, 1952, by H. G. Deignan; original number 194.

Diagnosis: From *Cr. o. ochraceus* separable by having the under parts a dark isabelline buff, deeper on the under tail coverts; from *henrici*, by complete absence of yellow suffusion over the under parts and by having the upper parts dark olivaceous-brown, not brownish olive; from *cambodianus*, by much richer coloration of the under parts and by having the upper parts a more rufescent, less ashy, olivaceous brown.

Range: Lowland evergreen forests of southwestern Thailand, north at least to lat. 14°40′ N., south at least to lat. 11°40′ N. (on the western side of the Tenasserim Range replaced by *Cr. o. ochraceus*).

Remarks: This new form is long-crested and thus cannot be linked with *Criniger tephrogenys*, a species still unknown in Thailand north of the Isthmus of Kra.

The colors of the under parts in the group are excessively difficult to convey in words. The under parts of *Cr. o. crinitus* are much like those of *Criniger tephrogenys gutturalis* (Borneo), but devoid of yellow suffusion. The under parts of true *ochraceus* are very like those of *Pycnonotus blanfordi conradi* of Thailand and Indochine.

ORNITHOLOGY.—*Notes on the generic affiliations of the great grebe of South America.* ALEXANDER WETMORE, Smithsonian Institution, and KENNETH C. PARKES, Carnegie Museum.

The great grebe found from southern Brazil and northern Chile (occasionally from the coast of Perú) to Tierra del Fuego was named *Colymbus major* by Boddaert in 1783. In 1862 Coues set up the genus *Aechmophorus* to include *Podiceps occidentalis* Lawrence, designated as the type of the new genus, and *Podiceps clarkii* Lawrence, the latter now known to be the female of *occidentalis*. The first authors to place Boddaert's species *major* in *Aechmophorus* appear to have been Sclater and Salvin (Nomenclator Avium Neotropicalium, 1873: 150), and it has been listed as *Aechmophorus major* in all the standard reference works on South American birds we have consulted, with the single exception of Brabourne and Chubb (Birds of South America, 1912: 27), who include *major* in *Podiceps*, with no reference to the genus *Aechmophorus*.

We propose to show (1) that the original generic diagnosis of *Aechmophorus* by Coues was inadequate and (2) that the species *major* belongs in the genus *Colymbus*, with *occidentalis* remaining as the only living member of *Aechmophorus*.

The principal characters invoked by Coues in his diagnosis involve the length and shape of the bill, shape of the outer primaries, and proportions of tarsus, middle toe, and outer toe. The form of the bill we regard as of little importance since the variation within the genus *Colymbus* as presently understood is already so great that the inclusion of the long-billed *major* is not unwarranted on this count. Bill-size in grebes in general is an allometric character; the larger the grebe, the longer, proportionally, is the bill. This is even noticeable within a species, e.g., compare *C. g. griseigena* with *C. g. holböllii*.

Aechmophorus occidentalis has the outermost primaries somewhat more sharply incised and more attentuated than any species of *Colymbus* (including *major*). This, however, is again a matter of degree, since there is much variation in this character among the species concerned.

Coues claimed that in *Aechmophorus* the outer lateral toe is "much longer than the middle," while in *Colymbus* the outer lateral toe is said to be "but little, if any, longer than the middle toe." This character does not hold true. The ratio of the outer to the middle toe measured and computed for four adult males each of *Aechmophorus occidentalis*, *Colymbus cristatus* (type species of the genus), and "*Aechmophorus*" *major* gives the following results:

occidentalis:	1.05, 1.07, 1.08, 1.09.
cristatus:	1.06, 1.06, 1.07, 1.09.
major:	1.04, 1.05, 1.05, 1.05.

It can easily be seen that *Aechmophorus* and *Colymbus* cannot be separated on this count and that the ratios for *major* average a little lower, away from the condition claimed for *Aechmophorus* by Coues.

Another character of proportion used by Coues involves the tarsus and the middle toe with claw. In *Aechmophorus* the tarsus is said to be as long as the middle toe and claw, while in *Colymbus* it is shorter. Using the same four specimens of each species as above, and computing the ratio between tarsus and middle toe with claw, the table below demonstrates that a separation can be made on this basis, but that *major* definitely falls with *Colymbus* rather than *Aechmophorus*:

occidentalis:	1.00, 1.04, 1.05, 1.07.
cristatus:	.91, .96, .97, .97.
major:	.92, .95, .97, .97.

Ogilvie-Grant (Cat. Birds Brit. Mus. **26**, 1898: 502) includes still another character in his key to the genera of grebes. In his "*Podicipes*" the secondaries are said to be equal to or not much shorter than the primaries, while in *Aechmophorus* the secondaries are short, with the longest about equal to the ninth or tenth primary. This character holds good for *occidentalis* versus *cristatus*, and in this matter of wing shape *major* is closer to *occidentalis*. However, when the other species of *Colymbus* are examined, the character breaks down,

as some specimens of *Colymbus caspicus* and *C. occipitalis* would fall into *Aechmophorus* if classification were to be attempted on the basis of this comparison of primaries and secondaries.

In his diagnosis of the genus *Aechmophorus*, Ogilvie-Grant (op. cit.: 549) states that the nuptial and winter plumages are alike. This is not true of the great grebe, which has a pronounced seasonal color change, but may be accepted for *occidentalis*, though in that species the winter plumage is actually slightly duller than the breeding dress.

A character, however, which separates *Aechmophorus* from *Colymbus* is the following: In *Aechmophorus* the culmen is somewhat flattened between the nostrils, which open almost directly upward; in *Colymbus* the culmen is ridged, often markedly, between the nostrils, which open in a more lateral direction. We have verified this in all the species of the latter genus except *taczanowskii*, which from the plate that accompanies the original description, is like its relatives. In bill form, *major* is like the species of *Colymbus*.

Perhaps one of the most important pieces of evidence that *major* is a *Colymbus* rather than an *Aechmophorus* is the color of the downy young. Like all of the other species of *Colymbus*, the downy *major* has a streaked pattern, best developed on the head, but present also on neck and back. The juvenal plumage also has some streaks on the face. *Aechmophorus occidentalis*, on the other hand, shows no streaks in any plumage, the downy young being a uniform gray, completely unlike any other grebe.

When the senior author first met the great grebe in life in Argentina he was so impressed by its difference in appearance from the western grebe that he secured skeletal material that is available for the present studies. In the osteology an impressive character marking *Aechmophorus occidentalis* is in the form of the braincase, which is elongated so that the cavity for the brain is enlarged longitudinally, and the actual brain capacity appears considerably increased. In fact, the forward extension of the cavity for the brain reduces appreciably the size of the interorbital opening between the two eyes.

In *Colymbus cristatus*, type of *Colymbus*, on the contrary, the brain case is relatively shorter, and the interorbital opening larger in the area immediately adjacent to the anterior part of the brain. The posterior part of the cranium appears broader and more abruptly truncated, particularly when viewed from above. The eared grebe and horned grebe both agree with *cristatus*, indicating that this conformation is one that is characteristic of the genus. The five skulls of *major* available are like those of *Colymbus cristatus*, differing in the same manner as does *cristatus* from *Aechmophorus occidentalis*.

In life the great grebe bears a striking resemblance to the red-necked grebe (*Colymbus grisegena*) in general form, color pattern, and actions, differing from the longer and more slender necked western grebe as does our familiar American form, *Colymbus grisegena holböllii*. To one familiar with the western grebe the differences in form and color are clear cut and striking.

We have no hesitance in transferring *major* to the genus *Colymbus*, where in the arrangement of species followed by Peters (Check-list Birds of the World **1**, 1931: 38–40) it should be placed at the end, following *grisegena*. It is our opinion, in conformity with this, that *Aechmophorus occidentalis* is the sole surviving species of its genus, a genus which, presumably, diverged early from the line that has produced *Colymbus*, since *Aechmophorus* seems in several ways more primitive than *Colymbus*, viz., in the plain plumage pattern of the downy young to which we have referred, also in the unspecialized color pattern of the adults, which resembles in general the immature and winter plumages of *Colymbus*.

Fossil remains of *Aechmophorus* from the Pleistocene of Fossil Lake, Oregon, have been described by L. H. Miller (Univ. Calif. Publ., Bull. Dept. Geol., **6**, 1911: 83) as *A. lucasi*. These differ from the living birds mainly in large size of the leg bones, with body and wing dimensions the same as modern *occidentalis*. Hildegarde Howard (Carnegie Inst. Washington Publ. **551**, 1946: 150) regards them as directly ancestral to the birds that today inhabit our western marshes.

NEW MEMBERS OF THE ACADEMY

There follows a list of persons elected to membership in the Academy, by vote of its Board of Managers, since June 1, 1951, who have since qualified as members in accordance with the bylaws (see also this Journal **42:** 309–312, 1952).

RESIDENT

Elected June 18, 1951

HERBERT F. SCHIEFER, physicist, National Bureau of Standards, in recognition of his contributions to fundamental knowledge of textile fibers and fabric structures.

Elected January 14, 1952

LAURISTON S. TAYLOR, chief, Atomic and Radiation Physics Division, National Bureau of Standards, in recognition of his outstanding contributions to X-ray physics.

Elected October 13, 1952

HERMAN BRANSON, professor, Department of Physics, Howard University, in recognition of his theoretical work in physics and application of radioactive isotopes.

GEORGE M. BRIGGS, chief, Nutrition Unit, Laboratory of Biochemistry and Nutrition, NIAMD, National Institutes of Health, in recognition of his contributions to the science of nutrition and in particular his work on newer vitamins of the B complex.

MARTHA S. CARR, commodity geologist (iron ore), Mineral Deposits Branch, U. S. Geological Survey, in recognition of her work on iron ore reserves in the United States and throughout the world and on the geologic history of the rocks of the District of Columbia.

STELLA LECHE DEIGNAN, director, Bio-Sciences Information Exchange, Smithsonian Institution, in recognition of her research in physical anthropology, particularly dermatoglyphics and more recently for her development and directorship of the Medical Sciences [now Bio-Sciences] Information Exchange.

IMMANUEL ESTERMANN, director, Material Sciences Division, Office of Naval Research, in recognition of his contributions to the science of physics, and in particular his researches on molecular beam techniques and solid state physics.

LLOYD N. FERGUSON, associate professor of chemistry, Howard University, in recognition of his research work in spectroscopy and his contributions of chemical reviews articles.

JOHN S. HALL, director, Equatorial Division, Naval Observatory, in recognition of his researches in astrophysics, particularly in the fields of spectrophotometry and polarization.

ROMAN KENK, science specialist, Library of Congress, in recognition of his extensive work on the taxonomy and physiology of fresh-water triclads.

OLAF MICKELSEN, assistant chief, Laboratory of Biochemistry and Nutrition, NIAMD, National Institutes of Health, in recognition of his work in the field of nutrition both in the field of experimental research as well as human nutrition.

HOWARD B. OWENS, science teacher and instructor in education, Northwestern High School, Hyattsville, Md., in recognition of his contributions to entomology and in particular his outstanding work as a teacher of science through which he has imparted sound knowledge and inspiration to the rising generation of scientists.

RANDAL M. ROBERTSON, science director, Research Group, Office of Naval Research, in recognition of his contributions to the science of physics, and in particular his work on the development of maritime electronic devices, including radar.

MODDIE D. TAYLOR, associate professor of chemistry, Howard University, in recognition of his research in vapor phase dissociation measurements relating to acid-base and hydrogen-bonding studies.

Elected November 17, 1952

HOWARD H. CAMPAIGNE, chief, Mathematical Research Division, Armed Forces Security Agency, in recognition of his services in the field of mathematics, especially in "restricted" fields.

CHARLES L. CHRIST, chief, X-ray Investigations Unit, Geochemistry and Petrology Branch, U. S. Geological Survey, in recognition of his services to the science and practice of X-ray crystallography.

CARROLL E. COX, professor of plant pathology, University of Maryland, in recognition of his teaching and research activities in the field of

plant pathology, particularly for his work on the mechanisms of fungicidal action.

WATSON DAVIS, director, Science Service, in recognition of his contributions to the interpretation and popularization of science and to scientific documentation.

HARRY L. FISHER, special assistant, Research and Development Branch, Synthetic Rubber Division, RFC, in recognition of his contributions to the organic chemistry of rubber, especially the mechanism of vulcanization, the development of adhesives from rubber derivatives, and his invention of the word "elastomer," which has now come into general use.

HUGH G. GAUCH, professor of plant physiology, University of Maryland, in recognition of his teaching and research activities in the field of plant physiology, particularly the mineral nutrition and biochemistry of plants.

HERBERT C. HANSON, research professor, Biology Department, Catholic University of America, in recognition of his contributions to ecology, range management, and the conservation movement.

ERNEST F. PRATT, associate professor of chemistry, University of Maryland, in recognition of his fundamental research in organic chemistry.

WILKINS REEVE, professor of chemistry, University of Maryland, in recognition of his studies in organic reaction mechanisms.

HENRY LEE SMITH, JR., assistant director, Foreign Service Institute, and director and professor of Linguistics, School of Language and Linguistics, Foreign Service Institute, Department of State, in recognition of his contributions to linguistics, especially for his co-authorship of the Outline of English Structure with Dr. George L. Trager, an outstanding analysis of English phonology.

ROBERT A. SPURR, associate professor of chemistry, University of Maryland, in recognition of his studies in infrared spectroscopy.

GEORGE L. TRAGER, director of linguistics research and professor of linguistics, Foreign Service Institute, Department of State, in recog nition of his work in linguistic theory and analysis, bringing out the fundamental nature of scientific linguistics as a part of anthropology.

CHARLES K. TRUEBLOOD, professor of psychology, American University, in recognition of his contributions to the psychology of personality and for his work in promoting intergroup relations through the annual institutes in human relations which he conducts.

PAGE E. TRUESDELL, acting head, Research and Analysis Division, Photographic Interpretation Center, U. S. Naval Receiving Station, in recognition of his contribution to geology and his research in photogeology and photobotany as directed toward the requirements of the military.

Elected December 15, 1952

CARL E. BEHRENS, operations analyst, Oper ations Evaluation Group, Office of Chief Naval Operations, in recognition of his contributions to the field of military operations research.

FRANCOIS N. FRENKIEL, senior staff physicist, Johns Hopkins University Applied Physics Laboratory, in recognition of his contributions to fluid dynamics, particularly his researches in turbulence, turbulent diffusion, atmospheric turbulence, and boundary layer phenomena.

PETER R. HOFSTAETTER, associate professor of psychology, Catholic University of America, in recognition of his contributions to social psychology, systematic psychology and quantitative methods in psychology.

JOHN L. KASK, assistant director, U. S. Fish and Wildlife Service, in recognition of his international leadership in fisheries research.

FRANK W. LAMB, scientific analyst, Operations Evaluation Group, Office of Chief of Naval Operations, in recognition of his contributions to the field of military operations research.

J. A. NEUENDORFFER, deputy director, Operations Evaluation Group, Office of Chief of Naval Operations, in recognition of his contributions to the field of military operations.

BENNET A. PORTER, entomologist and leader, Division of Fruit Insect Investigation, U. S. Bureau of Entomology and Plant Quarantine, in recognition of his ability and accomplishments as an investigator in the field of fruit insect investigations.

RAYMOND A. ST. GEORGE, entomologist, U. S. Bureau of Entomology and Plant Quarantine, in recognition of his research on insects injurious to forest and shade trees and to forest products.

RAYMUND L. ZWEMER, adviser on research, Library of Congress, in recognition of his studies on the endocrine factors involved in general body resistance to disease, radiation and other noxious stimuli.

Elected January 12, 1953

CLARENCE H. HOFFMANN, entomologist and assistant to the director of research, U. S. Bureau of Entomology and Plant Quarantine, in recognition of his contributions to the biology and control of forest insects and the effects of DDT on fauna.

THOMAS H. JOHNSON, director, Division of Research, Atomic Energy Commission, in recognition of his contributions to physics, in particular his researches in the field of wave mechanical properties of molecular beams and on the nature of the primary cosmic radiation.

Elected February 16, 1953

FRANK GONET, principal commodity expert, Chemicals, U. S. Tariff Commission, in recognition of his contributions in the field of chemistry and chemical economics with particular reference to the Tariff Commission's annual publication on Synthetic Organic Chemicals, U. S. Production and Sales and Imports of Coal-Tar Products.

ARCHIE I. MAHAN, physicist, Naval Ordnance Laboratory, in recognition of his contributions to the geometrical optics of lens systems and to the physical optics of optical systems.

BERNICE G. SCHUBERT, taxonomist, Division of Plant Exploration and Introduction, Plant Industry Station, Beltsville, Md., in recognition of her monographic studies in *Desmodium* and *Begonia*, editorial work in preparing the 8th edition of Gray's Manual of Botany, and floristic study of the Belgian Congo.

Elected March 16, 1953

LEONARD CARMICHAEL, Secretary of the Smithsonian Institution, in recognition of his contributions to physiological and experimental psychology, to education, and to science administration.

Elected April 13, 1953

WILLIAM H. AVERY, chemist, member of Principal Staff and Supervisor of Propulsion, Johns Hopkins University Applied Physics Laboratory, in recognition of his work in the field of physical chemistry, and in particular his researches in infrared spectroscopy and chemical kinetics, as well as the science and technology of combustion phenomena.

HUGH CARTER, chief of Marriage and Divorce Analysis Branch, National Office of Vital Statistics, Department of Health, Education, and Welfare, in recognition of his contribution to demography, especially his studies in migration and family structure as these relate to health.

VIRGINIA GRIFFING, associate professor of chemistry, Catholic University of America, in recognition of her use of ultrasonics in basic chemical researches.

C. K. JEN, physicist, member of Principal Staff and Supervisor of Electricity and Magnetism in Research Center, Johns Hopkins University Applied Physics Laboratory, in recognition of his work in the fields of electronics and spectroscopy, and in particular his researches on the ionosphere and in microwave physics.

FRANK T. MCCLURE, physicist, member of Principal Staff and Chairman, Research Center, Johns Hopkins University Applied Physics Laboratory, in recognition of his work in the field of physical chemistry, in particular his researches in statistical thermodynamics and the technology of rockets and guided missiles.

HOMER E. NEWELL, JR., head, Rocket-Sonde Research Branch Radio Division I, Naval Research Laboratory, in recognition of his leadership in investigations of the physics of the upper atmosphere.

HENRY W. OLSON, associate professor, Wilson Teachers College, in recognition of his contributions to biology and in particular his researches on the physiology and taxonomy of earthworms.

SHIRLEIGH SILVERMAN, physicist, member of Principal Staff and assistant supervisor of Chemical Physics in Research Center, Johns Hopkins University Applied Physics Laboratory, in recognition of his work in the field of molecular physics, in particular his researches in infrared spectroscopy.

BENJAMIN L. SNAVELY, physicist, U. S. Naval Ordnance Laboratory, in recognition of his contributions to acoustics, and in particular his researches into the measurement and analysis of sound waves and vibrations.

CHARLES S. SPOONER, JR., chief, Relief Map Division, Army Map Service, in recognition of his research into the problems of 3-dimensional mapping, and in particular his studies on molded aerial photographs.

HENRY P. WARD, professor of chemistry, Catholic University of America, in recognition of his noteworthy contributions in the field of synthetic organic chemistry.

Elected October 12, 1953

HOWARD W. BOND, senior scientist, U. S. Public Health Service, Laboratory of Tropical Diseases, National Institutes of Health, in recognition of his contributions to biochemistry, and in particular his researches on the synthesis of compounds of possible value for the treatment of diseases.

CARL C. DAUER, medical adviser, National Office of Vital Statistics, in recognition of his outstanding contributions to epidemiology, including geographic variation in the incidence of and other aspects of the epidemiology of poliomyelitis, diphtheria, malaria, and other communicable diseases, as well as noncommunicable diseases such as appendicitis and heart disease.

RICHARD L. DOLECEK, head of Cryogenics Branch, Electricity Division, Naval Research Laboratory, in recognition of his research in low temperature physics.

FELIX FRIEDBERG, instructor, department of Biochemistry, Howard University Medical School, in recognition of his contributions to biochemistry, particularly his researches on protein metabolism.

MALCOLM C. HENDERSON, expert, Planning Staff, Atomic Test Operations, Federal Civil Defense Administration, in recognition of his contributions to nuclear physics, and his part in the development of specialized sonar equipment for submarines during the war.

KEITH C. JOHNSON, head, Department of Science Division 1, D. C. Public Schools, in recognition of his contributions to science education, particularly the organization and conduct of the Annual Science Fair for Greater Washington.

JOHN A. O'BRIEN, JR., associate professor of biology, Catholic University of America, in recognition of his contributions to cytology, particularly his investigations of cytoplasmic inclusions in specialized plant cells.

RONALD S. RIVLIN, consultant and head, Theoretical Mechanics Section, Naval Research Laboratory, in recognition of his contributions to theories of finite elastic deformations, the outstanding contribution to this field in the last decade.

MARTIN C. STEELE, head, Cryomagnetics Section, Cryogenics Branch, Electricity Division, Naval Research Laboratory, in recognition of his contributions to cryogenics, and in particular his researches upon superconductivity.

RAYMOND E. WILSON, acting chief, Heat and Power Division, National Bureau of Standards, in recognition of his leadership in the field of thermometry and his personal contributions to that field.

Elected November 17, 1953

R. TUCKER ABBOTT, associate curator, Division of Mollusks, U. S. National Museum, in recognition of his contributions to malacology, especially his researches on medically important snails.

NORMAN R. S. HOLLIES, research associate, Harris Research Laboratories, in recognition of his contributions to the measurement and interpretation of the dielectric constants of ionic solutions, in particular, proteins and amino acids.

LYLE T. ALEXANDER, principal soil scientist, U. S. Soil Conservation Service, in recognition of outstanding research in varied fields of soil chemistry and physics, particularly that pertaining to soil chemistry research and the use of radioactive material in relation to plant growth.

FRANKLIN E. ALLISON, principal soil scientist, Soils Division, U. S. Department of Agriculture, in recognition of outstanding research in the field of soil organic matter and the biochemistry of soil.

GEORGE ANASTOS, associate professor of zoology, University of Maryland, in recognition of his services in the science of acarology.

ERVIN H. BRAMHALL, chief physicist, Office Chief of Ordnance, Department of the Army, in recognition of his contributions to geophysics, and in particular his work on aurora and magnetic fluctuations.

HAROLD J. CAUL, research associate, National Bureau of Standards, in recognition of his outstanding researches on dental materials and his engineering work in the construction of a pilot plant for the extraction of alumina from clay.

KENNETH G. CLARK, senior chemist, Division of Fertilizer and Agricultural Lime, U. S. Department of Agriculture, in recognition of his contributions to fertilizer technology, his keenly analytical approach to chemical research, and his command of statistics.

LAWRENCE M. AMES, senior mycologist, Engineer Board, Fort Belvoir, Va.. in recognition of his productive studies of cellulelytic fungi.

LYMAN A. DEAN, principal soil scientist, Division of Soil and Plant Relationships, U. S.

Department of Agriculture, in recognition of his investigations with radioisotopes, particularly phosphorus, in soil and plant sciences.

P. ARNE HANSEN, professor of veterinary bacteriology, University of Maryland, in recognition of his research in bacteriology and investigations in the Lactobacteriaceae.

MARJORIE HOOKER, geologist, U. S. Geological Survey, in recognition of her contributions to the bibliography of geological sciences and mineral geography.

KENNETH D. JACOB, head chemist in charge, Division of Fertilizer and Agricultural Lime, U. S. Department of Agriculture, in recognition of his outstanding research on the phosphate industry and participation in the varied problems of fertilizer research.

LOUIS R. MIZELL, manager, Textile Processing Division, Harris Research Laboratories, in recognition of his research on the relationship of molecular structure of wool to its properties, and his researches on wool processing.

MARGARET RUTH TODD, geologist, U. S. Geological Survey, in recognition of her contributions to paleontology, particularly her studies of fossil foraminifera.

COLIN W. WHITTAKER, in charge Liming Materials Investigations, U. S. Department of Agriculture, in recognition of his researches on the chemistry of fertilizers and fertilizer materials, especially on chemical reactions in fertilizer mixtures and between isolated components of such mixtures. Other important contributions are those on preparation of potassium nitrate and on thermodynamics of nitrogen-hydrogen mixtures.

DAVID A. YOUNG, JR., entomologist, U. S. Bureau of Entomology and Plant Quarantine, in recognition of his contributions toward an improved knowledge of leafhopper classification.

Elected December 14, 1953

MARTIN TOSCAN BENNETT, consulting chemical engineer, in recognition of his pioneering work in the field of gas engineering, a subdivision of chemical engineering, in which he has applied the sciences of chemistry and physics to the engineering aspects of (and rates for) domestic and industrial utilization of natural gas; and his technologic contributions to international resource studies (unpublished).

DANIEL FRISHMAN, research associate, Harris Research Laboratories, in recognition of his work on the chemistry and physics of textile fibers.

EDSON J. HAMBLETON, staff assistant, Foreign Technical Programs, U. S. Bureau of Entomology and Plant Quarantine, in recognition of original contributions in taxonomy (especially in the tingids and coccids), and in the life histories and control of destructive insects (especially those of cotton, in Peru); distinguished service in connection with locust-control programs of the U. S. Technical Collaboration Administration in countries of the Near East and the Far East.

CHARLES M. MOTTLEY, director, Planning Division, Office of the Assistant Secretary of Defense (R. & D.), in recognition of contributions in the field of limnology, biometrics and operations analysis.

DEWEY STEWART, senior agronomist, Division of Sugar Plant Investigation, U. S. Department of Agriculture, in recognition of research in plant pathology, especially in relation to breeding of sugar beet varieties for resistance.

HARLEY N. GOULD, professional associate, Bio-Sciences Information Exchange, Smithsonian Institution, in recognition of his professional attainment in biology and physical anthropology.

NONRESIDENT

Elected October 13, 1952

MILDRED STRATTON WILSON, Anchorage, Alaska, in recognition of her contributions to the systematic knowledge of fresh-water and marine copepods.

Elected December 15, 1952

RICHARD L. HOFFMAN, laboratory shift supervisor, Radford Arsenal, Radford, Va., in recognition of his excellent systematic studies of the Diplopoda.

Elected December 14, 1953

BRUCE W. HALSTEAD, head of Department of Ichthyology and Herpetology, School of Tropical and Preventive Medicine, College of Medical Evangelists, Loma Linda, Calif., in recognition of his contribution to the field of medical ichthyology, especially icthytoxism in fishes.

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